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PRODUCTION OF GRISEOFULVIN BY *PENICILLIUM RAISTRICKII*

By P. W. BRIAN, P. J. CURTIS and H. G. HEMMING

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Griseofulvin, previously known as a metabolic product of *Penicillium griseofulvum* Dierckx, *P. nigricans* (Bain.) Thom and *P. urticae* Bain., has now been found to be produced by some strains of *P. raistrickii* Smith. Strains of this species vary in their capacity to produce sclerotia and conidia in culture; those strains that produce abundant sclerotia produce few conidia, those that produce abundant conidia produce few sclerotia. Conidial strains produce good yields of griseofulvin but sclerotial strains produce little or none.

INTRODUCTION

A *Penicillium* isolate, attributed to the *P. raistrickii* series but not identified to species, was obtained from an acid heath soil (Jefferys, Brian, Hemming & Lowe, 1953). This differed from *P. raistrickii* Smith in having smooth conidiophores and tangled conidial chains. Culture filtrates showed no antibacterial activity and little antifungal activity other than a tendency to stunt the germ-tubes of *Botrytis allii* in a spore germination assay. We have also examined two similar fungi obtained by Warcup (1951) from Breckland soil. One of these produced culture filtrates with negligible antibacterial and antifungal activity, but the other produced culture filtrates exhibiting the germ-tube distorting activity characteristic of griseofulvin (Brian, Curtis & Hemming, 1946; Brian, 1949). This observation led us to investigate a number of strains of *Penicillium raistrickii*; our results are described briefly below.

MATERIALS AND METHODS

Methods of culture and assay were those described by Brian *et al.* (1946). All cultures were incubated at 25° C.

The following strains of *P. raistrickii* were used:

No. 335: received from National Collection of Type Cultures, in 1946, as *P. raistrickii* Smith (NCTC 4153).
No. 453: received in 1948 from J. H. Warcup as *Penicillium* sp. (*raistrickii* series) B15b (see Warcup, 1951).
No. 454: origin as 453, Warcup's strain B15d.
No. 1006: *Penicillium* sp. (*raistrickii* series), isolated from an acid heath soil (see Jefferys *et al.* 1953).
No. 1113B: received in 1953 from Centraalbureau voor Schimmelcultures (C.B.S.), Baarn, as *P. raistrickii* Smith, Pehrson strain.
No. 1114: received in 1953 from C.B.S. as *P. raistrickii* Smith, C.B.S. strain.

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No. 1127: received in 1954 from G. Smith, *P. raistrickii* Smith, NRRL 2039.
No. 1128: origin as 1127, *P. raistrickii* Smith, type culture, BB. 100.
No. 1129: origin as 1127, *P. raistrickii* Smith, BB. 100A.
No. 1130: origin as 1127, *P. raistrickii* Smith, BB. 100B.

The conidial structure and basic colony features of all these were completely characteristic of *P. raistrickii* as described by Smith (1933) and Raper & Thom (1949), except 453, 454, 1006, 1113B and 1114; these five strains, while agreeing with *P. raistrickii* in all other respects, produced smooth or almost smooth conidiophores on Czapek agar or malt agar, and the conidial chains were loosely parallel or tangled rather than columnar.

The ten strains varied in the freedom with which they produced conidia and sclerotia on agar media. Strains producing abundant sclerotia produced conidia sparsely; strains producing abundant conidia produced relatively few sclerotia; a few strains were intermediate between the two preceding groups. This distinction could be seen on Czapek agar and on malt agar, though the former medium was more favourable to production of conidia. Strains 335, 454, 1127 and 1128 were predominantly conidial; strains 453, 1006, 1129 and 1130 were predominantly sclerotial; strains 1113B and 1114 were intermediate. On liquid Czapek-Dox and Raulin-Thom media these differences were even more marked; sclerotial strains produced felts consisting of immense numbers of sclerotia embedded in sterile mycelium and conidia were almost completely absent; conidial strains produced heavily sporing felts with no sclerotia and intermediate strains lightly or moderately sporing felts with few or no sclerotia.

From two strains (453, 1006) the metabolic product terrein has been isolated (Grove, 1954); this substance is also produced by *Aspergillus terreus*.

RESULTS

The strains were grown on a variety of media, all containing chloride added as potassium chloride or as hydrochloric acid in the initial pH adjustment. Chloride is essential for griseofulvin production. Nitrogen sources compared have included sodium nitrate, ammonium tartrate, ammonium sulphate and hydrolysed casein; carbon sources, at 5 and 10 % levels, have included glucose, sucrose, lactose and glycerol. All media were initially adjusted to pH 5·0 and samples of culture filtrates assayed for griseofulvin at intervals during a period of about 30 days. In general, sodium nitrate and ammonium tartrate were the most favourable nitrogen sources for griseofulvin production, glucose and sucrose the most favourable carbon sources.

In Table 1 the maximum apparent griseofulvin concentration found by bioassay is given for each strain (*a*) for the best medium for each strain, (*b*) for Raulin-Thom medium (5 % glucose) with added KCl (0·05 %), which was a good medium for most strains. It will be seen that indications of griseofulvin-like activity have been obtained from eight of the ten cultures. There were wide variations in the activity observed, highest activity being found in culture filtrates from conidial strains, no activity or negligible activity from sclerotial strains, moderate activity from intermediate strains.

In our experience griseofulvin-like activity in the *Botrytis allii* bioassay is confined, among natural products to griseofulvin, dechlorogriseofulvin (MacMillan, 1951, 1953) and the bromo-analogue of griseofulvin (MacMillan, 1954). The activity observed in the experiments reported here is likely to be due mainly to griseofulvin, though it is possible that dechlorogriseofulvin production might be of importance. The metabolic products of one high-yielding strain (335) and two low-yielding strains (453 and 1114) have been examined. From strain 335 the only active material isolated was of m.p. 222° C.; this did not depress the m.p. (222° C.) of authentic griseofulvin, and showed an infra-red spectrum identical with that of griseofulvin. Strains 453 and 1114 yielded insufficient material to make identification possible.

Table 1. *Production of griseofulvin by* Penicillium raistrickii

Strain no.	Maximum apparent yield of griseofulvin by bioassay (mg./l.) On Raulin-Thom	On optimal medium for the strain	Type of growth
335	51·2	102·4	Conidial
453	—	3·2	Sclerotial
454	51·2	102·4	Conidial
1006	—	—	Sclerotial
1113B	1·6	12·8	Intermediate
1114	3·2	6·4	Intermediate
1127	51·2	51·2	Conidial
1128	102·4	102·4	Conidial
1129	—	0·8	Sclerotial
1130	—	—	Sclerotial

DISCUSSION

Griseofulvin has previously been recorded as a metabolic product of the following species: *Penicillium griseofulvum* Dierckx (Oxford, Raistrick & Simonart, 1939), *P. urticae* Bain. (Jefferys *et al.* 1953), *P. patulum* Bain. (Brian, Curtis & Hemming, 1949), *P. janczewskii* Zal. (Brian *et al.* 1949) and *P. nigricans* (Bain.) Thom (Jefferys *et al.* 1953). Of these, the first three are all included by Raper & Thom in *P. urticae*, though there is some doubt in our minds whether *P. griseofulvum* should be so included, and the last two in *P. nigricans*. The results presented in this paper show that griseofulvin production is also characteristic of the species *P. raistrickii* Smith. They also suggest that the definition of the species could be usefully widened to include strains with smooth conidiophores and non-columnar conidial chains (e.g. our 453, 454, 1006, 1113B and 1114).

The demonstrated relation between sporulation and griseofulvin production is interesting and suggestive. A connexion between sporulation and griseofulvin production has also been suggested to us by two other observations. Griseofulvin is produced by *P. nigricans*; we have not been able to obtain griseofulvin from certain strains very similar in all respects to *P. nigricans* save that they produce few conidia, which we have referred to *P. albidum* Sopp. Furthermore, we have been unable to produce griseofulvin from *P. nigricans* or *P. raistrickii* in submerged culture, although the organisms grow well under such conditions; these two species do not in our experience produce conidia in submerged culture, though they sporulate vigorously in surface culture. On the other hand, *P. griseofulvum*, which under certain conditions does sporulate in submerged culture (Morton, 1955), also produces griseofulvin under such conditions. These observations should not necessarily be taken to mean that griseofulvin is produced only in the conidia of appropriate species of *Penicillium*. It may well be present in the conidia, it is certainly also present in considerable quantities in mycelium from which most spores have been removed (Brian *et al.* 1949), and its presence in culture filtrates which have had no direct contact with the upper, sporing surface of felts in surface culture, is also indicative of production in the mycelium. We can only conclude at this stage that sporulation and griseofulvin synthesis appear to be in some way related.

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REFERENCES

Brian, P. W. (1949). Studies on the biological activity of griseofulvin. *Ann. Bot., Lond.*, N.S. **13**, 59–77.

Brian, P. W., Curtis, P. J. & Hemming, H. G. (1946). A substance causing abnormal development of fungal hyphae produced by *Penicillium janczewskii* Zal. I. Biological assay, production and isolation of 'curling factor'. *Trans. Brit. mycol. Soc.* **29**, 173–187.

Brian, P. W., Curtis, P. J. & Hemming, H. G. (1949). A substance causing abnormal development of fungal hyphae produced by *Penicillium janczewskii* Zal. III. Identity of 'curling factor' with griseofulvin. *Trans. Brit. mycol. Soc.* **32**, 30–33.

Grove, J. F. (1954). The structure of terrein. *J. chem. Soc.* (5591), 4693–4694.

Jefferys, E. G., Brian, P. W., Hemming, H. G. & Lowe, D. (1953). Antibiotic production by the microfungi of acid heath soils. *J. gen. Microbiol.* **9**, 314–341.

MacMillan, J. (1951). Dechlorogriseofulvin—a metabolic product of *Penicillium griseofulvum* Dierckx and *Penicillium janczewskii* Zal. *Chem. & Ind.*, p. 719.

MacMillan, J. (1953). Griseofulvin. Part VII. Dechlorogriseofulvin. *J. chem. Soc.* pp. 1697–1702.

MacMillan, J. (1954). Griseofulvin. Part IX. Isolation of the bromo-analogue from *Penicillium griseofulvum* and *Penicillium nigricans*. *J. chem. Soc.* pp. 2585–2587.

Morton, A. G. (1955). Unpublished results.

Oxford, A. E., Raistrick, H. & Simonart, P. (1939). Studies in the biochemistry of microorganisms. LX. Griseofulvin, $C_{17}H_{17}O_6Cl$, a metabolic product of *Penicillium griseofulvum* Dierckx. *Biochem. J.* **33**, 240–248.

Raper, K. B. & Thom, C. (1949). *A manual of the penicillia*. London: Ballière, Tindall & Cox.

Smith, G. (1933). Some new species of *Penicillium*. *Trans. Brit. mycol. Soc.* **18**, 88–91.

Warcup, J. H. (1951). The ecology of soil fungi. *Trans. Brit. mycol. Soc.* **34**, 376–399.

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FUSARIUM DISEASES OF PEAS

By E. W. BUXTON

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(With Plate 14 and 1 Text-figure)

Cultures of *Fusarium oxysporum* and *F. oxysporum* var. *redolens*, isolated from diseased pea plants growing in east England, differed in their pathogenicity. Most cultures of *F. oxysporum* behaved like the American physiologic race 1 of *F. oxysporum* f. *pisi*, but some were only weak pathogens and one infected pea varieties resistant to races 1 and 2. This is provisionally named race 3A. A culture of *F. oxysporum* var. *redolens* caused a wilt indistinguishable from that caused by race 1 of *F. oxysporum* f. *pisi*. Pea wilt was the main cause of crop failures due to Fusaria up to mid-June.

Pathogenic and non-pathogenic forms of *F. solani* were also isolated from diseased peas, but usually only after mid-June. From plants showing characteristic footrot, only *F. solani* was isolated, but towards the end of June many diseased plants had symptoms characteristic of both wilt and footrot. These symptoms are thought to resemble those previously called 'St John's Disease', and from such plants both *F. oxysporum* and *F. solani* were always isolated.

When *F. oxysporum* f. *pisi* race 1 was inoculated to peas together with either pathogenic or non-pathogenic cultures of *F. solani*, the pea plants were less severely affected than when inoculated with race 1 alone.

INTRODUCTION

Failure of pea crops has been held to be caused by many different organisms. Pea wilt was attributed by Heimbeck (1954) entirely to L-forms of bacteria and by Oostenbrink (1951) to nematodes, mostly *Heterodera göttingiana* Liebscher. Although nematodes have often caused failures, there is much evidence that wilts and rootrots can be caused by the soil fungi *Aphanomyces euteiches* Drechsl., *Thielaviopsis basicola* (Berk. & Br.) Ferraris, and several *Fusarium* species.

Van Hall (1903) isolated *F. vasinfectum* Atk. var. *pisi* from peas suffering from what he called 'St John's Disease', because the disease occurred on or near St John's Day (24 June). Schikorra (1906) and Guéguen (1915) recorded a similar disease in Germany, and isolated several taxonomically distinct pathogenic Fusaria from the diseased plants. Turesson (1920) attributed a Swedish pea disease to *F. viticola* Thüm. Bisby (1918, 1919) described species of *F. oxysporum* Fr. affecting peas in Minnesota. Wollenweber (1913) reported that *F. orthoceras* App. & Wollenw. and *F. redolens* Wollenw. (a new species) caused pea wilt and footrot and stated that several other species of Fusarium caused 'St John's Disease'.

Jones (1923) concluded that *F. oxysporum*, *F. solani* (Mart.) Sacc., *F. sclerotioides* Sherb. and *F. redolens* were only weakly pathogenic, and that peas fail in the U.S.A. mainly because of footrot caused by *F. martii* App. & Wollenw. var. *pisi* Jones (syn. *F. solani* f. *pisi* (Jones) Snyder &

Hansen). Linford (1928) described peas wilting without any footrot and found the cause to be *F. orthoceras* App. & Wollenw. var. *pisi* (Lindf.). Togashi (1928) attributed pea diseases near Tokyo to *F. arthrosporioides* Sherb., *F. anguidioides* Sherb. and *F. sporotrichioides* Sherb. Snyder (1933) and Snyder & Walker (1935) gave the name 'near-wilt' to a condition caused by *F. orthoceras* var. *pisi*, distinguished from the disease described by Linford (1928) by the slower development of symptoms; the fungus infected pea varieties resistant to wilt. In their review of the classification of Fusaria, Snyder & Hansen (1940) referred the isolates causing wilt and near-wilt to *F. oxysporum* f. *pisi* (Lindf.) Snyder & Hansen races 1 and 2, respectively. Since the discovery of these two physiologic races of *F. oxysporum* f. *pisi*, other pea varieties have been bred resistant to both fungi, notably Wisconsin Perfection and Alaska, resistant to race 1, and Rogers K resistant to race 2. Wells, Hare & Walker (1949) showed that the variety Delwiche Commando resisted both Fusarium races, as also does New Era (Hagedorn, 1953), bred by crossing Delwiche Commando and Wisconsin Perfection.

Schreuder (1951) showed that an isolate of *F. oxysporum* which caused wilt in Holland could infect American pea varieties resistant to races 1 and 2. She called this isolate 'race 3' and considered that it caused the disease called by van Hall (1903) 'St John's Disease'.

In Britain, only footrot, caused by *F. solani* f. *pisi*, has been investigated (Ogilvie & Mulligan, 1931), but Buxton & Storey (1954) showed that pea wilt also occurs and is caused by strains of *F. oxysporum* Fr. emend. Snyder & Hansen and *F. oxysporum* Fr. emend. Snyder & Hansen var. *redolens* (Wollenw.) Gordon. In 1953 wilt appeared earlier than footrot, though both occurred in some diseased crops. *F. oxysporum* and *F. solani* were both isolated from many diseased plants, especially in mid-season, and it seemed possible the two might combine to give some characteristic syndrome. The experiments described in this paper were designed to see what effects double inoculations of *F. oxysporum* and *F. solani* have on the pea plant, and to gain information on the pathogenic races of *F. oxysporum* f. *pisi* that occur in England.

DISEASE SYMPTOMS

The observations of field crops over a wide area of the pea-growing districts of England are described by Buxton & Storey (1954). Three Fusaria were isolated from diseased plants: *F. oxysporum*, *F. oxysporum* var. *redolens* and *F. solani*. Plants yielding the first two of these Fusaria showed typical wilt, as described by Linford (1928). The vascular tract of the root and lower part of the stem was coloured a reddish orange, but the cortex was not damaged. The plants had wilted and their yellow and brittle leaves were rolled under along the mid-veins; they were stunted and bore no pods. *F. solani* was isolated from many plants with footrot. This disease is characterized by the cortex of the hypocotyl becoming black, by root decay, stunting and yellowing of the plant and a brilliant red discoloration of the vascular tract of the root. This discoloration does not normally extend up the stem. The leaves of plants suffering from wilt begin to turn yellow at the margins, the yellowing later extending inwards, whereas the leaves of plants with footrot turn yellow uniformly and do not typically roll under their mid-veins.

Many plants showed symptoms not easily identified as those of wilt or footrot. From such plants both *F. oxysporum* and *F. solani* were consistently isolated, and occasionally *F. oxysporum* var. *redolens*. From plants with both fungi, *F. oxysporum* was invariably isolated from higher up the plant than *F. solani*; it could always be found in the vascular tract of the lower part of the stem, whereas *F. solani* was the dominant fungus in the rotted cortex of the stem base and roots.

INOCULATION EXPERIMENTS

Tests using isolates of Fusarium oxysporum

Experiments were done in an unheated glasshouse, and continued from April until October. Plants were grown from seed in wooden boxes containing unsterilized John Innes potting compost. Plants of a uniform height (*c.* 4 in.) were inoculated by four methods:

(*a*) Plants were grown in soil from badly infested fields.

(*b*) Maize-meal sand inoculum (3% maize-meal and 13% water, inoculated with *Fusarium* 3 weeks beforehand) was placed in the soil beneath each seed at planting time.

(*c*) Spore suspensions of *Fusarium* were poured on the surface of the soil.

(*d*) Plants were transplanted and inoculated by the method of Wells *et al.* (1949). Surplus soil was shaken from the seedlings, whose roots were then dipped for 5 sec. in a dense spore suspension of the *Fusarium.*

All the methods succeeded and produced similar results, but (*d*) was adopted for routine work because it gave better quantitative results. Plants uniform in size could always be chosen and poor emergence, which limited the value of the other three methods, was avoided. When *F. oxysporum* was inoculated to a differential host range to identify physiological races, methods (*b*) and (*d*) were both used, in parallel tests.

Seven English isolates from wilted peas were compared with four from America and Holland and inoculated to peas of variety Onward, susceptible to race 1 (Cruickshank, 1951), and Delwiche Commando and New Era, resistant to race 2 (Hagedorn, 1953). Symptoms appeared some 20–25 days after inoculation.

Table 1 shows that five of the English isolates were pathogenic on Onward peas (Pl. 14, fig. 1). Two isolates caused wilt in Delwiche Commando and New Era (Pl. 15, fig. 2), showing a previously undescribed race of *F. oxysporum* f. *pisi*. Most of the isolates tested behaved like race 1. Plants inoculated with *F. oxysporum* var. *redolens* wilted less severely than those infected with other English isolates. The two isolates that caused wilting in Delwiche Commando and New Era varieties were later inoculated to pea varieties Alaska, Alderman, Dwarf Grey Sugar and Wisconsin Perfection, all resistant to race 1 (Walker, 1931), and both Fusaria caused wilt in all four varieties. Five strains of Greenfeast peas, selected in New

Zealand for resistance to wilt, did not wilt when inoculated with isolates 2 and 3 (Table 1). In all the experiments, fragments of root and stem of diseased plants were surface-sterilized with 1 % silver nitrate and plated on potato-dextrose agar medium. Plants infected with race 1 and *F. oxysporum* var. *redolens* yielded isolates from the stele up to 1 in. above the hypocotyl, whereas in those infected with the American race 2 and nos. 4 and 5 (Table 1), the fungus was found in the vascular tracts above the 4th node (*c.* 4 in. from the hypocotyl).

Table 1. *Incidence of wilting in an inoculation experiment using eleven isolates of* Fusarium oxysporum. *Pea varieties Onward (susceptible to race* 1*), and Delwiche Commando and New Era (both resistant to race* 1 *and race* 2*) were used*

			Pea varieties inoculated		
Isolate no.	Species	Origin of isolate	Onward	Delwiche Commando	New Era
1	*F. oxysporum* var. *redolens*	Var. Kelvedon Triumph	20	0	0
2	*F. oxysporum*	Var. Onward	20	0	0
3	*F. oxysporum*	Var. Kelvedon Triumph	16	0	0
4	*F. oxysporum*	Var. Onward	20	6	0
5	*F. oxysporum*	Var. Meteor	20	20	20
6	*F. oxysporum*	Var. not known	0	0	0
7	*F. oxysporum*	Var. Onward	10	—	—
8	*F. oxysporum* f. *pisi* race 1	Wageningen, Holland	10	—	—
9	*F. oxysporum* f. *pisi* race 2	Wageningen, Holland	20	—	—
10	*F. oxysporum* f. *pisi* race 1	Wisconsin, U.S.A.	20	—	—
11	*F. oxysporum* f. *pisi* race 2	Wisconsin, U.S.A.	16	0	0

Isolates 1 to 7 are from wilted plants in England.
The figures show the number of plants wilted out of twenty inoculated.

Infection by Fusarium oxysporum *and* F. solani

Many of the diseased plants in the field showed wilt and footrot together, with varying degrees of symptoms characteristic of each disease. Both *F. oxysporum* and *F. solani* were isolated from these plants. A few of the isolates did not affect pea seedlings to which they were inoculated, suggesting that they were secondary invaders of already feeble plants. Plants already wilted, from which *F. oxysporum* was isolated, showed initial footrot symptoms, caused by *F. solani*. An experiment was done combining pathogenic and non-pathogenic isolates of *F. oxysporum* and *F. solani*. Seven replicated inoculation types, including 30 plants of variety Onward in each treatment, were used. The treatments were as follows: (1) pathogenic *F. solani* f. *pisi* alone; (2) pathogenic *F. oxysporum* f. *pisi* alone; (3) inoculum (1) and (2) together; (4) inoculum (2), followed 4 days later by inoculum (1); (5) inoculum (2), together with non-pathogenic *F. solani*; (6) inoculum (1), together with non-pathogenic *F. oxysporum*; (7) control, inoculated with tap water—these were transplanted twice to fit with treatment (4). Disease incidence, mean heights (measured from the hypocotyl) and mean weights of the plants (excluding roots) in each set are shown in Table 2. Plants from some of the treatments are shown in Pl. 14, fig. 3.

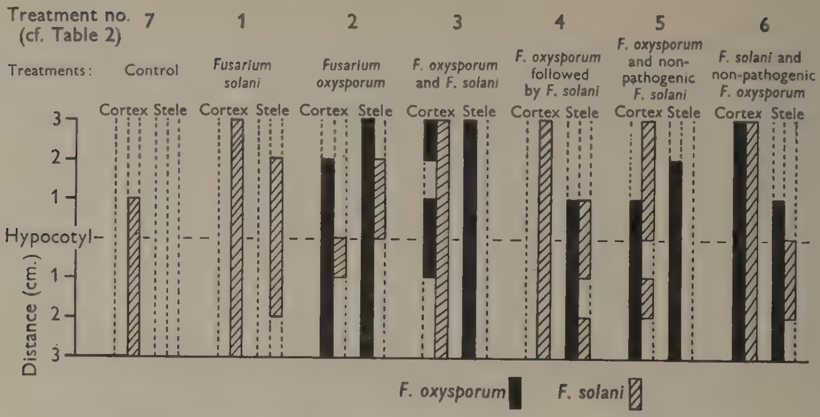
Table 2 shows that all the inoculations produced symptoms similar to those observed in the field (Buxton & Storey, 1954). Inoculating with *F. oxysporum* or *F. solani* alone diminished the mean heights and mean weights of the plants. Each of these sets was more severely diseased than those in which a combined inoculum was used. Plants inoculated with both pathogenic species (treatment 3) were less affected than when inoculated with either alone (treatments 1 and 2). Inoculating plants simultaneously with non-pathogenic *F. solani* and pathogenic *F. oxysporum* (treatment 5) also had less effect on the plants than inoculation with *F. oxysporum* alone (treatment 2).

Table 2. *Disease recordings and symptoms of peas, var. Onward, inoculated with combinations of* Fusarium oxysporum *and* F. solani

t- it	Inoculum	Disease numbers	Incidence (%)		Mean heights of plants (cm.)	Mean dry weights of plants (g.)	External symptoms
			Wilt	Footrot			
	F. solani f. *pisi*	25/28	0	89·4	12·1	0·15	Leaves yellow, plants stunted. Footrot severe
	F. oxysporum f. *pisi*	23/27	85·0	0	14·9	0·19	Leaves rolled, plants wilted. Cortex clean
	F. solani f. *pisi* + *F. oxysporum* f. *pisi*	26/30	53·3	86·8	13·6	0·24	Leaves yellow, plants only partly wilted. Footrot
	F. oxysporum f. *pisi* followed by *F. solani* f. *pisi* 4 days later	23/28	82·4	82·4	12·1	0·19	Leaves yellow, dry. Plants severely wilted. Footrot severe
	F. oxysporum f. *pisi* + non-pathogenic *F. solani*	17/28	60·9	0	15·7	0·22	Leaves rolled, plants partly wilted. Slight footrot
	F. solani f. *pisi* + non-pathogenic *F. oxysporum*	25/25	0	100	13·3	0·15	Leaves yellow, dry. Plants stunted. Footrot severe
ol	—	0/30	0	0	20·3	0·35	Healthy. Leaves all green

The distribution of the Fusaria in the infected plants used in the experiment was determined by plating many fragments, each 5 mm. long, of diseased material from the roots and the lower part of the stem. Fragments were cut from measured positions along the root and stem, and surface-sterilized (1% silver nitrate) before plating on potato-dextrose agar medium. The distribution of the two fungi in all seven treatments (see Table 2) is shown in Text-fig. 1.

Each fungus invades the vascular tract of the root when present on its own (treatments 1 and 2). In plants infected with pathogenic *F. oxysporum*, together with pathogenic or non-pathogenic *F. solani* (treatments 3 and 5), *F. solani* does not reach the stele. Non-pathogenic *F. oxysporum* can invade the stele and enter the stem when inoculated together with pathogenic *F. solani* (treatment 6). Pathogenic *F. oxysporum* does not persist in the cortex in the presence of pathogenic *F. solani* (treatments 3 and 4).



Text-fig. 1. Distribution of *F. oxysporum* and *F. solani* in infected plants from experiments (cf. Table 2).

Discussion

There seems little doubt that the disease syndrome known on the continent of Europe as 'St John's Disease' also occurs in England. In this country it can be split into three components: wilt (caused by *F. oxysporum* f. *pisi* and, to a less extent, *F. oxysporum* var. *redolens*), footrot (caused by *F. solani* f. *pisi*) and the condition to which perhaps the name might correctly be ascribed, *F. oxysporum* and *F. solani* acting together. Pea failures due to Fusaria during the early part of the growing season, mid-May to mid-June, are mainly caused by *F. oxysporum* f. *pisi* race 1, whereas from mid-July onwards they are caused by *F. solani*. Simultaneous infections by both fungi are common in late June. Went (1934), in Holland, isolated several Fusaria from peas which had wilt and footrot symptoms. She concluded that the disease, which was called 'St John's Disease', was caused by *F. solani* var. *striatum* (Sherb.) Wollenw., *F. solani* var. *martii* and *F. oxysporum*. The first two of these are synonymous with *F. solani* (Mart.) App. et Wollenw., fide Snyder & Hansen (1941). Snyder (1935) also concluded that part of the 'St John's Disease' complex in Germany was the same as footrot (Jones, 1923) caused by *F. solani* f. *pisi*.

If the name 'St John's Disease' is worth retaining, it ought to refer to the disease pattern most prevalent near the end of June. In Britain, most Fusarium diseased peas at that time yield both *F. oxysporum* and *F. solani*. This 'double-infection' phase of disease might therefore be analogous to the 'St John's Disease' as described by Went.

The new race of *F. oxysporum* f. *pisi* demonstrated in this paper is similar to Schreuder's 'Race 3', for it causes wilt in the varieties Delwiche Commando and New Era, both resistant to race 2. Schreuder did not test her isolate on variety New Era, so it is too early to draw conclusions concerning the possible identity of the new Dutch and English strains. It is proposed that the English strain be called *F. oxysporum* f. *pisi* race 3A until further comparisons and tests of pathogenicity can be made.

The existence of non-pathogenic *F. oxysporum* and *F. solani* in the soil increases the difficulty of interpreting the exact causes of 'St John's Disease'. Many isolates of *Fusarium* from diseased plants have proved to be non-pathogenic. Such fungi probably enter plants already enfeebled by other causes such as an earlier infection by pathogenic Fusaria. Plating diseased fragments from many field specimens showed that *F. oxysporum* was consistently prevalent in the stele of the stem and that *F. solani* occurred in the cortex of the hypocotyl region. The results of plating diseased material from inoculation experiments (Text-fig. 1) confirmed this distribution of the fungi in the plant. Both Fusaria were present in the root stele. Non-pathogens of both species can enter the plants and invade the cortex and vascular tracts

Many plants, early in the season, show incipient footrot symptoms; they also show wilt and *F. oxysporum* can be isolated from the stele. It may be inferred that such plants were primarily suffering from wilt and became secondarily invaded by *F. solani*.

The decrease of symptoms caused by inoculating *F. solani* along with *F. oxysporum* (Table 2) might have several causes; one may be interference with toxins produced by the pathogenic *F. oxysporum*. McLure (1951) and Bega (1954), working with *Ipomaea batatas* (Sweet potato), showed that plants inoculated with *Fusarium solani* f. *batatas* Bega and then later with *F. oxysporum* f. *batatas* (Wollenw.) Snyder & Hansen, did not develop wilt as severe as those infected with *F. oxysporum* alone. Bega suggested that the footrot caused by *F. solani* protected the plants from infection by *F. oxysporum*. The inoculation experiments with pea Fusaria showed that both pathogenic and non-pathogenic *F. solani* depress the wilting produced by *F. oxysporum* f. *pisi*.

Where non-pathogenic *F. solani* was inoculated along with *F. oxysporum*, little or no footrot developed, hence the suppression is unlikely to be of a similar nature to that proposed by Bega.

My thanks are due to Dr W. L. Gordon, Winnipeg, Canada, for confirming the identifications of some of the pea Fusaria; to Dr D. J. Hagedorn, Wisconsin, U.S.A., and the Ferry Morse Seed Co., U.S.A., for supplying pea seed of American varieties.

REFERENCES

Bega, R. (1954). Biological control of Fusarium wilt of Sweet Potato. *Phytopathology*, **44**, 482.

Bisby, G. R. (1918). A Fusarium disease of garden peas in Minnesota. *Phytopathology*, **8**, 77.

Bisby, G. R. (1919). Studies on Fusarium diseases of potatoes and truck crops in Minnesota. *Bull. Minn. agric. Exp. Sta.* no. 181, 1–58.

Buxton, E. W. (1955). Fusarium diseases of Gladiolus. *Trans. Brit. mycol. Soc.* **38**, 193.

Buxton, E. W. & Storey, I. F. (1954). The occurrence of pea wilt in Britain. *Plant Pathology*, **3**, 13–16.

Cruickshank, I. A. M. (1951). Pea-wilt in New Zealand. *N.Z. J. Sci. Tech.* A, **33**, 75–80.

Guéguen, F. (1915). Sur une maladie du collet du pois. *Ann. Épiphyt.* (*Mem. et Rap.*), **2**, 302–309.

HAGEDORN, D. J. (1953). The New Era canning pea. *Bull. Wis. agric. Exp. Sta*, no. 504.

HALL, C. J. VAN (1903). Die Sankt-Johanniskrankheit der Erbsen, verursacht von *Fusarium vasinfectum* Atk. *Ber. dtsch. bot. Ges.* **21**, 2–5.

HEIMBECK, L. S. (1954). *On the etiology of brown roots, yellowing and wilt due to 'B type (Dienes) L. (Klieneberger) forms' of Bacteria, with special reference to Pea Wilt.* Oslo: Dreyers Forlag.

JONES, F. R. (1923). Stem and rootrot of peas in the United States caused by species of *Fusarium. J. agric. Res.* **26**, 459–476.

LINFORD, M. B. (1928). A Fusarium wilt of peas in Wisconsin. *Bull. Wis. agric. Exp. Sta*, no. 85, 1–44.

McLURE, T. T. (1951). Fusarium footrot of sweet potato sprouts. *Phytopathology*, **41**, 72–77.

OGILVIE, L. & MULLIGAN, B. O. (1931). Pea-sickness, an important disease of field peas. *Gdnrs.' Chron.* **90**, 122.

OOSTENBRINK, M. (1951). Het Erwtencystenaaltje *Heterodera göttingiana* Liebscher, in Nederland. *Tijdschr. PlZiekt.* **57**, 52–64.

SCHIKORRA, G. (1906). Fusarium-Krankheiten der Leguminosen. *Arb. biol. Abt.* (*Anst.-Reichsanst.*), *Berl.* **5**, 157–188.

SCHREUDER, J. C. (1951). Een onderzoek over de Amerikaanse Vaatziekte van Erwten in Nederland. *Tijdschr. PlZiekt.* **57**, 175–207. (With English summary.)

SNYDER, W. C. (1933). A new vascular wilt of peas. *Science*, N.S., **77**, 327.

SNYDER, W. C. (1935). St John's Disease of pea in Europe. *Zbl. Bakt.* **91**, 449.

SNYDER, W. C. & HANSEN, H. N. (1940). The species concept in *Fusarium. Amer. J. Bot.* **27**, 64–67.

SNYDER, W. C. & HANSEN, H. N. (1941). The species concept in Fusarium with reference to section Martiella. *Amer. J. Bot.* **28**, 738.

SNYDER, W. C. & WALKER, J. C. (1935). Fusarium near-wilt of pea. *Zbl. Bakt.* **91**, 355–378.

TOGASHI, K. (1928). Three Fusaria which cause the wilt disease of pea. *Jap. J. Bot.* **4**, 153–188.

TURESSON, G. (1920). *Fusarium viticola* Thüm. infecting peas. *Bot. Notiser*, **4**, 113–125.

WALKER, J. C. (1931). Resistance to Fusarium wilt in garden, canning and field peas. *Bull. Wis. agric. Exp. Sta*, no. 107, 1–15.

WELLS, D. G., HARE, W. W. & WALKER, J. C. (1949). Evaluation of resistance and susceptibility in garden pea to near-wilt in the greenhouse. *Phytopathology*, **39**, 771–779.

WENT, J. C. (1934). Fusarium-aanstastingen van Erwten. *Proefschrift, Utrecht*, 1934.

WOLLENWEBER, H. W. (1913). Studies on the Fusarium problem. *Phytopathology*, **3**, 24–50.

EXPLANATION OF PLATE 14

Fig. 1. Plants of var. Onward, showing wilt symptoms, from experiments: (*a*) control, (*b*) inoculated with *Fusarium oxysporum* var. *redolens*, (*c*) inoculated with *F. oxysporum* (English isolate—treatment no. 4 of Table 1), (*d*) inoculated with *F. oxysporum* f. *pisi* (American isolate—treatment no. 10 of Table 1). (× ⅓.)

Fig. 2. Plants of var. New Era showing wilt symptoms: (*a*) control, (*b*) inoculated with *F. oxysporum* (English isolate—treatment no. 5 of Table 1). (× ⅛.)

Fig. 3. Typical plants var. Onward, from an experiment with six different inoculation types, including combinations of *F. oxysporum* and *F. solani*. Treatments (cf. Table 2) were: (*a*) *F. solani* f. *pisi* together with *F. oxysporum* f. *pisi*; (*b*) *F. oxysporum* f. *pisi* followed by *F. solani* f. *pisi* 4 days later; (*c*) *F. oxysporum* f. *pisi* together with non-pathogenic *F. solani*; (*d*) *F. solani* f. *pisi* together with non-pathogenic *F. oxysporum*. The arrows indicate the hypocotyls, from which heights were measured.

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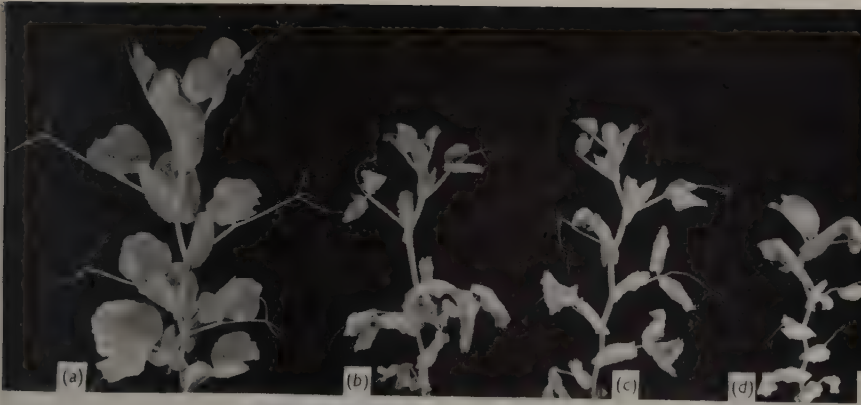

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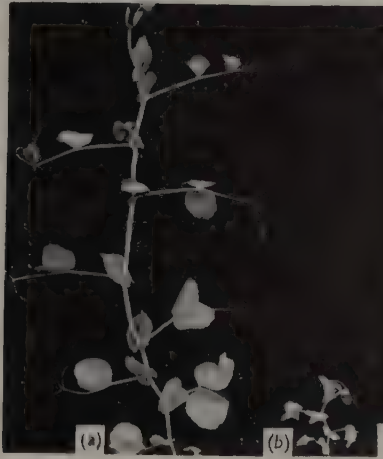

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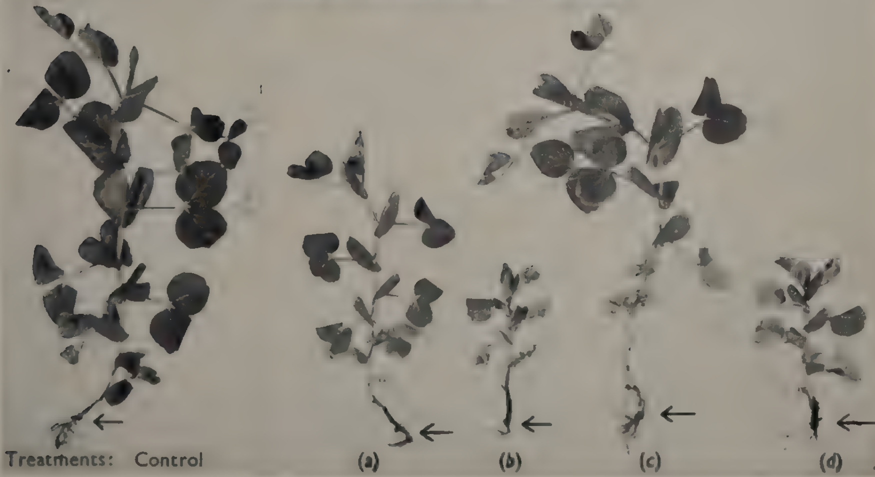

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Trans. Brit. mycol. Soc. **38** (4), 317–334 (1955).

OBSERVATIONS ON GASTEROMYCETES. 1–3

By J. T. PALMER

5 *Station Road, Woodley, Stockport, Cheshire*

(With 3 Text-figures)

No. 1. *Geastrum floriforme* Vitt. is recorded for Britain with a discussion of the literature and a description of the British specimens.

No. 2. Five specimens (including the lectotype), from the Persoon Herbarium, of *G. rufescens* Pers. em. van Wav. (syn. *G. fimbriatum* Fr.) are described and illustrated, the literature relating to the species is reviewed, the development of the fruit body is described, and *G. vulgatum* Vitt. is suggested as the legitimate name for *G. rufescens* sensu Fr.

No. 3. Basidia differing from the normal form in the Homobasidiomycetes have been observed in *G. triplex* and *G. rufescens*. *G. triplex* has a basidium which develops a tapering epibasidium, the tip of which swells into a capitellum on which six (to eight?) spores form on sterigmata. The basidium of *G. rufescens* is similar, but the epibasidium is clavate and the spores are occasionally borne on the upper sides. It is suggested that the basidia in *Geastrum* might be used for establishing natural relationships within the genus and distinguishing between critical taxa.

Introduction

Whilst specimens of *Astraeus*, *Geastrum* and *Myriostoma* have always aroused interest when found, they have received surprisingly little serious study in this country. The fruit-bodies of *Geastrum* and its allies are leathery and persistent, except for the fleshy layer, which usually flakes away or rapidly decays, hence collectors often pick up old and weathered specimens, and all too frequently descriptions have been based on material of this kind. During a study of the group, the writer has been able to locate the habitats of several species in the field and so to study them in different stages of development. This has resulted in a number of observations which do not appear to have been previously published. In addition, a study of types in the Persoon Herbarium has been undertaken.

Technique

Erythrosin B in 10% ammonia, as demonstrated by Dr F. B. Hora at the British Mycological Society's Autumn Foray at Bangor, 1950, is a suitable protoplasmic stain for basidia, and makes a good background for non-staining hyaline structures such as the exospore. The mountant temporarily fixes the tissue and, after a period of several weeks, the section can still be examined by reflooding with the mountant without any apparent deterioration. No distortion has been found when tissues so stained have been compared with others mounted in distilled water.

In geaster eggs, the basidia are fugacious. However, they can be readily preserved by drying in a warm oven, although some deliquescence usually occurs. The dried tissue can then be soaked out in Erythrosin ammonia, or some other suitable reagent, when required for examination.

All drawings in these notes have been made freehand, and microscopic characters measured in the above-mentioned mountant.

Discrepancies between spore measurements given by various workers may be due to whether or not the spines or verrucae have been included. Some species have the exospore forming a regular structure, but in others it is much sparser and occasionally irregular. Measurements are therefore given for the diameter of each spore to the nearest half micron without and with the ornamentation; the formulae showing the minimum, mean and maximum dimensions.

Herbarium numbers prefixed 'H.L.B.' refer to the Herbarium Lugduno Batavorum in the Rijksherbarium, Leiden, and 'J.T.P.' to the author's collection.

Nomenclature

In accordance with the International Code of Botanical Nomenclature, Persoon's spelling '*Geastrum*' is used instead of '*Geaster*' which was introduced by Micheli (1729) and later used by Fries (1829) and others. As '*Geastrum*' is an orthographic variant of '*Geaster*' it is unnecessary to treat species originally described in *Geaster* as new combinations, as has sometimes been done.

Acknowledgements

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No. 1. *GEASTRUM FLORIFORME* VITT.

On 1 November 1952, the author collected a minute, strongly hygroscopic geaster with a naked, indeterminate mouth (J.T.P. 75) in the flower-bed of a private garden at Blundellsands, on the Lancashire coast near Liverpool. This was subsequently determined as *G. floriforme* Vitt., a species not previously recorded for this country (Palmer, 1952). On 24 October 1953, one battered specimen with the upper part of the endoperidium completely destroyed (J.T.P. 75*a*) was collected on the same spot, and no specimens were found during 1954.

In previous years, *G. bryantii* Berk. was fairly plentiful under the privet hedge bordering the garden, and it was whilst searching for this species that the new record was made. The garden was neglected during the war years but the flower-beds have since been in cultivation. Blundellsands is a dune district, and a sample of sandy soil in which the geaster grew gave a reaction indicating pH 8 with Universal Testing Papers.

Literature

Vittadini (1843) described and figured as *Geaster floriformis* a form with an elongated-ovoid endoperidium and a papillate, indeterminate mouth. Morgan (1887) published as a new species *G. delicatus* from Lincoln, Neb., U.S.A., described as having a strongly hygroscopic exoperidium, a sessile, depressed-globose endoperidium and the mouth stellate-lacerate or sometimes a mere slit or puncture with spores measuring 5–6μ diameter. Hollós drew Lloyd's attention to the fact that *Geastrum floriforme* and *G. delicatum* are conspecific and *G. floriforme* Vitt. the valid name, which Lloyd (1903) was able to confirm.

Delimitation of the species

The key characters to this species would appear to be (*a*) the indeterminate mouth, (*b*) the hygroscopic nature of the exoperidium, (*c*) the spore size, and (*d*) the small fruit-body size. It has a superficial resemblance to *Astraeus hygrometricus*, which is readily distinguished by the generally larger size, branched, septate capillitium and larger spores (7–11μ) and to *Geastrum mammosum* and *G. hungaricum* Hollós, both of which have clearly delimited mouths. The last very minute species has not yet been found in Britain and, whilst formerly considered to be a synonym of *G. floriforme*, has been shown to be a distinct species by Staněk (1953).

Cunningham (1926) gave a spore range for *G. floriforme* of 5·4–7·4μ, separating *G. simulans* Lloyd, a species apparently confined to Australia, by the spores 4–5μ, subhygroscopic habit and manner in which the basal portion of the exoperidium becomes arched and carries upwards the endoperidium. He considered the two to be distinct and not, as might be surmised, that *G. simulans* was a small-spored form of *G. floriforme*.

Most workers give similar spore dimensions to Cunningham's, but there are some differences. Hollós (1904) mentioned spores as being occasionally only 4·5μ diam. Petri (1909) gave a range of 4–5μ and separated *G. floriforme* in his key from both *G. fimbriatum* and *G. vulgatum* by the very long pseudo-columella, although other workers describe this structure as being 'rounded' (Bottomley, 1948) or even 'inevident' (Long & Stouffer, 1948), whilst giving the hygroscopic exoperidium and indeterminate, lacerate, papillate mouth in his description. Long & Stouffer (1948) reported spores as measuring 4–7μ. Bottomley (1948) used the spore range 6–7μ when separating the species from *Astraeus hygrometricus* in her key, although giving the spores as 3·6–7μ in the description (probably a misprint). Staněk (1953) has followed Saccardo in giving *Geastrum floriforme* with spores 3·5–4μ and capillitium 6–7μ and *G. hungaricum* with spores 4–6μ and capillitium 2–4μ. However, he has kindly examined a sample of gleba and a drawing of J.T.P. 75, and considers the British collection to be correctly identified. He writes that, in young specimens, the mouth is tubularly papillate but, in old material, it is flattened, detached and torn.

The diameter of the rays of expanded specimens given by most workers falls within the range of 2–3·5 cm. However, Long & Stouffer (1948) gave specimens from their region as being 1–2·5 cm. diam., both Hollós (1904) and N. J. G. Smith (1935) reported specimens less than 1 cm. diam. in times of drought whilst Cunningham (1926, 1944) described the species as being 2–6 cm. across when expanded.

Type material

In the type-folder of *G. floriforme* at Kew is authentic material which Vittadini apparently sent to Berkeley. The specimens are firmly glued to the sheet, hence exoperidial characters are difficult to confirm, but the mouths, though badly mutilated, appear to have been papillate. A sample of gleba agrees well with the British material and has coarsely verrucose spores, 5–6–6·5 × 4·5–5–5·5 μ diam., with verrucae, 6–6·5–7·5 × 5–6–7 μ, and capillitium 2–8 μ diam. (Fig. 1*f*).

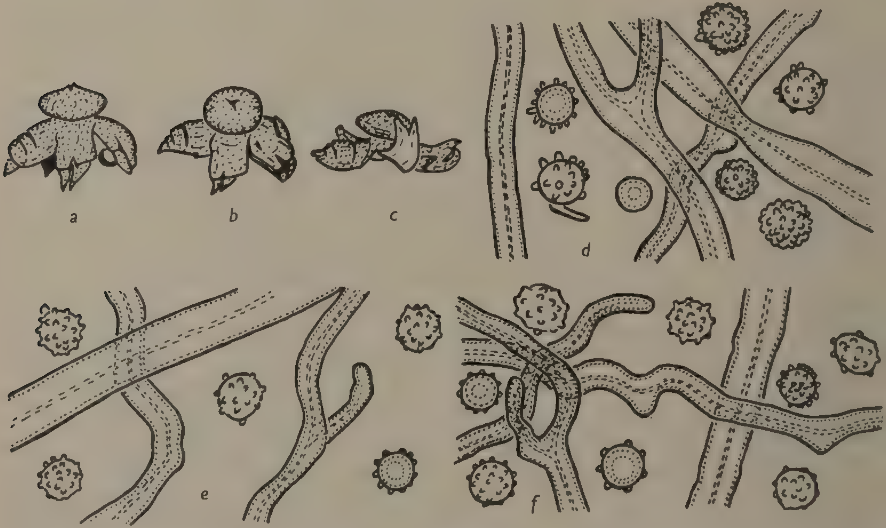

Fig. 1. *Geastrum floriforme* Vitt. *a–c*, J.T.P. 75, moist to dry, × 1; *d*, spores and capillitium, × 1000. *e*, J.T.P. 75a, spores and capillitium, × 1000. *f*, Vittadini's specimen, Herb. Kew, spores and capillitium, × 1000.

Description of British material (*J.T.P.* 75 *and* 75*a*) (Fig. 1*a–e*)

Exoperidium 2–2·5 cm. diam. with rays expanded. *Rays* 5 to 7, mainly broadly acuminate with blunt tips tending to subdivide and splitting two-thirds of the way to the middle, becoming recurved when moistened and tending to close over the endoperidium when dry (hygroscopic). In both specimens, the hygroscopic nature tended to diminish with age with rays drying expanded to incurved (Fig. 1 *c*), although there was no doubt of their belonging to the hygroscopic series. *Base* umbilicate. *Mycelial layer* absent, leaving *Fibrillose layer* silvery grey and smooth. *Fleshy layer* sepia to blackish brown (specimens had been expanded some time when collected, and this tissue was probably a different colour when freshly opened), about 1 mm. thick, persistent, tough and horny, assuming a 'rubbery' texture when moistened, cracked and fissured. *Endoperidium* 8 × 3·5 mm., greyish sepia, somewhat shiny although scurfy, depressed-globose, sessile. *Mouth* indeterminate, a plane, apical, irregularly torn aperture. *Gleba* dark brown. (The *Pseudo-columella* could not be studied as there was only one good specimen available, the second having the upper part of the endoperidium missing.) *Capillitium* deeply coloured, threads much interwoven, aseptate, thick-walled to almost solid with lumen usually discernible, of simple threads, mainly 1000–1500μ long, tapering at both ends to about 2μ diam., very irregular and sinuous with occasional short side branches towards the tips, up to 7·5μ diam. *Spores* deeply coloured, globose to irregular or ellipsoid, thick-walled, 1-guttulate, sparsely and coarsely verrucose, with an occasional short pedicel stump, 5–6–8 × 4–5·5–7μ, with verrucae, 6–7–9 × 5–6·5–7·5μ.

Specimen J.T.P. 75 has been deposited in Herb. Kew.

No. 2. Studies of type material: No. 1, *Geastrum rufescens* Pers. em. van Wav.

Geastrum rufescens Pers. (but often attributed to Fr.) and *G. fimbriatum* Fr. are two species which have been traditionally understood and separated chiefly by spore size and colour.

G. fimbriatum Fr. is probably one of our commonest geasters, and occurs abundantly in certain thickets on the Lancashire dunes, but '*G. rufescens* of authors' seem to be much less frequent, although freshly expanded specimens have been found in fair quantity on a scrub-covered hillside in north Derbyshire during the past 2 years.

An examination of the authentic material of *G. rufescens* Pers. from the Herbarium Lugduno Batavorum, Leiden, showed it to consist of five sheets containing six specimens:

(1) *H.L.B. no.* 910,262–393, in bottle no. 128 zw. (zw. = zwart, refers to the blank ink used) (Fig. 2 *a–c*). Designated as lectotype by G. L. van Eyndhoven, 13 February 1937. A single, loose specimen measuring approximately 6 × 3 cm., with eight wedge-shaped to acute rays, approximately 2 cm. long, splitting half-way to middle, irregular in size. *Exoperidium* somewhat saccate. *Mycelial layer* ochraceous, persistent but tending to separate from the fibrillose layer, encrusted with soil and coniferous needles. *Fibrillose layer* creamy ochre, tough, shining. *Fleshy layer* a dried, adnate, brownish layer with occasional fissures or cracks. *Endoperidium* 2·8 cm. diam. (flattened), probably originally subglobose, and appeared to be sessile and seated within the *Exoperidium* (saccate), with a smooth to finely encrusted surface. *Mouth* indeterminate, torn. *Gleba* brown. *Capillitium* light coloured, aseptate, thick-walled with lumen clearly apparent, of simple threads mainly 1000–1300μ long, tapering at

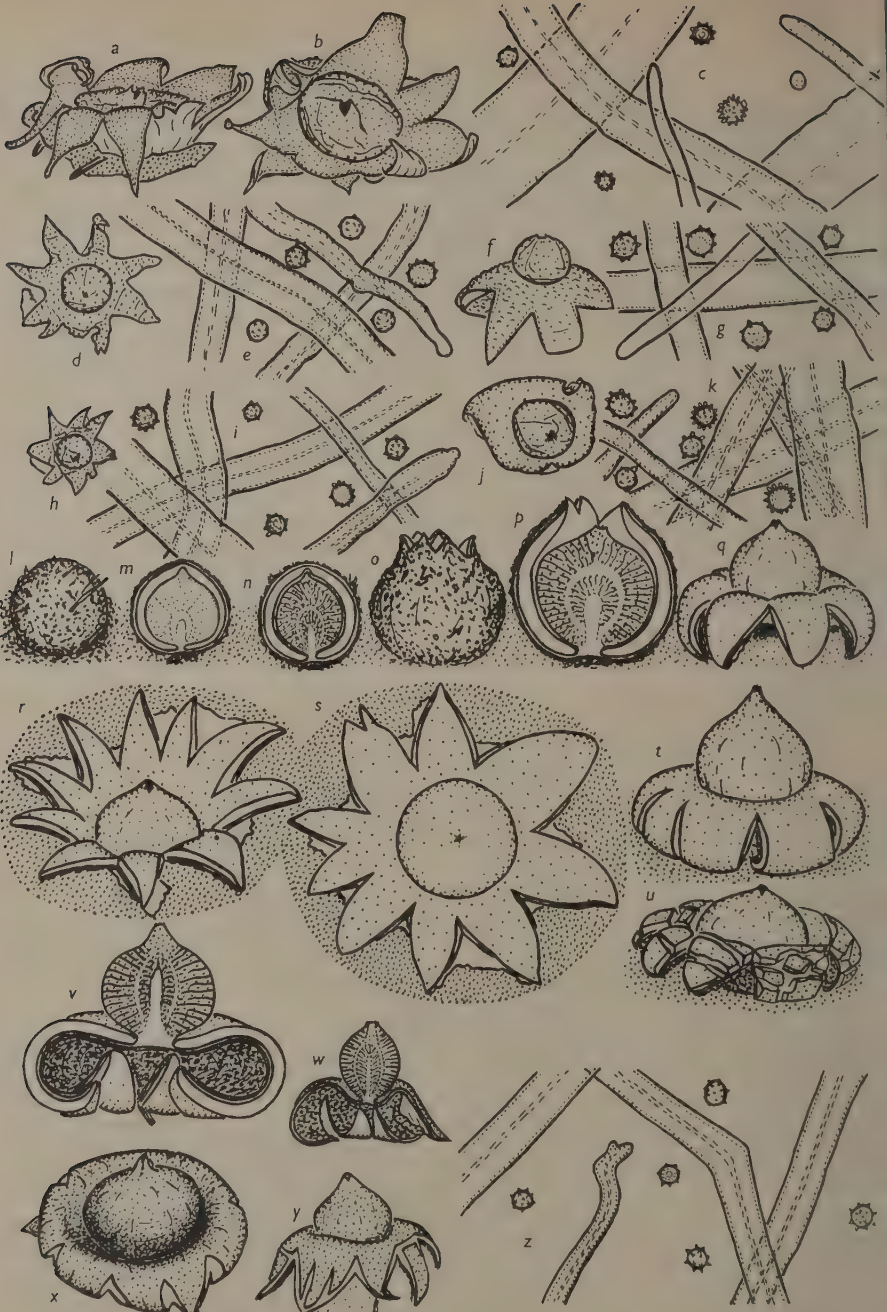

Fig. 2. *Geastrum rufescens* Pers. em. van Wav. *a*, *b*, lectotype, H.L.B. no. 910,262–393, different views, ×1; *c*, spores and capillitium, ×1000. *d*, H.L.B. no. 910,256–1383, ×½; *e*, spores and capillitium, ×1000. *f*, H.L.B. no. 910,256–1394, ×½; *g*, spores and capillitium, ×1000. *h*, H.L.B. no. 910,258–220, ×½; *i*, spores and capillitium, ×1000. *j*, H.L.B. no. 910,262–396, ×½; *k*, spores and capillitium, ×1000. *l–z*, fresh material from Freshfield, Lancs. *l–n*, unexpanded eggs, whole and vertical sections showing immature and mature gleba, ×1. *o–p*, expanding eggs, whole and vertical section, ×1. *q–v*, freshly expanded specimens, ×1. (*u*, specimen with much-cracked fleshy layer; *v*, vertical section.) *w–y*, old expanded and weathered specimens, ×1. (*w*, vertical section.) *z*, spores and capillitium, ×1000.

each end to blunt tips 1·5–3·5 μ diam., occasionally nodular with very infrequent short side branches towards the tips, up to 12·5 μ diam. *Spores* light-coloured, globose to occasionally irregular or ellipsoid, bluntly spinose to punctate, 1-guttulate, occasionally with brief apiculus, 2–3–3 × 2–3–3 μ, with spines, 2·5–3·5–4 × 2–3·5–4 μ. Without locality.
= *G. fimbriatum* Fr.

(2) *H.L.B. no.* 910,256–1383 (Fig. 2*d–e*). A single, glued-down specimen labelled in Persoon's handwriting '*Geastrum rufescens*' and '*Ex Lotheringia circa Nanceium ad terram in sylvis*'. About 4 cm. diam. *Rays* 7, wedge-shaped. *Exoperidium* somewhat saccate, with a dried-up reddish brown *fleshy layer*. *Endoperidium* ochraceous-brown, apparently sessile. *Mouth* indeterminate. *Capillitium* approximately 1000 μ long, 2–10 μ diam. *Spores* 2·5–3–3 × 2–2·5–3 μ, with spines, 3–3·5–4 × 2·5–3–4 μ.
= *G. fimbriatum* Fr.

(3) *H.L.B. no.* 910,256–1394 (Fig. 2*f–g*). The sheet contains two glued-down specimens. The first is a recurved specimen with 6 *rays*, about 4 cm. diam. *Exoperidium* with ragged remnants of reddish ochre *fleshy layer* adhering. *Endoperidium* sessile, ochraceous-brown. *Mouth* partly destroyed, probably indeterminate. *Capillitium* about 800 μ long, 2–10 μ diam. *Spores* 2·5–3–3·5 × 2·5–3–3·5 μ, with spines, 3–3·5–4·5 × 3–3·5–4 μ.
= *G. fimbriatum* Fr.

The second specimen, referred doubtfully to *G. rufescens* in Persoon's handwriting, is *Astraeus hygrometricus* (Pers.) Morg.

(4) *H.L.B. no.* 910,258–220 (Fig. 2*h–i*). Labelled in Persoon's handwriting '*Am. Borealis*' and both '*Geastrum rufescens?*' and '*G. pumilum*'. A single, glued-down specimen about 2 cm. diam. with 8 wedge-shaped to acuminate *rays*. *Exoperidium* saccate, with adnate, ochraceous-brown *fleshy layer*. *Endoperidium* sessile, purplish-brown. *Mouth* indeterminate, lighter than Endoperidium. *Capillitium* about 800 μ long, 2–10 μ diam. *Spores* 2·5–3–3·5 × 2·5–3–3·5 μ, with spines, 3–3·5–4·5 × 3–3·5–4 μ.
= *G. fimbriatum* Fr.

(5) *H.L.B. no.* 910,262–396 (Fig. 2*j–k*). A single, glued-down specimen about 3·5 cm. diam. with *rays* obscured beneath. *Exoperidium* with an adnate ochraceous-brown *fleshy layer*. *Endoperidium* concolorous, apparently sessile. *Mouth* indeterminate, shiny. *Capillitium* fragmented during examination, 2–10·5 μ diam. *Spores* 3–3·5–3·5 × 2·5–3–4 μ, with spines, 3·5–4–4·5 × 3–4–4 μ.
= *G. fimbriatum* Fr.

Note. With all specimens, except the lectotype, glued to sheets, it was not easy to form definite conclusions. At first sight, no. 3 appeared to closely resemble the traditional '*G. rufescens*' with its raggedly adhering fleshy layer, but the spore dimensions left little doubt as to its true affinity. All five specimens possessed the small spores, whilst most also had the thin, papery fibrillose layer, with the shiny, creamy-ochraceous surface where the mycelial layer had separated, so characteristic of *G. fimbriatum*. The capillitia were much interwoven and easily fragmented during teasing-out.

Literature

Persoon (1801) cited under *G. rufescens* both Schaeffer (1762), tab. 182, and Schmidel (1782), tabs. 43 and 50, figs. 1–3. Schaeffer's figures closely resemble what has been called '*G. rufescens*' and show a regularly toothed mouth, which Fries (1829) and later authors regarded as a major character. Schmidel, Tab. 43, depicts typical specimens of '*G. rufescens*' (which agree very well with the Derbyshire material referred to *G. vulgatum* Vitt.), whilst Tab. 50 shows four figures (not three) under '*Fig. II ad Tabula XLIII*' which are very good representations of *G. fimbriatum*, although Fries (1829) followed Persoon in referring both plates to '*G. rufescens*'. He cited Micheli (1729; tab. 100, fig. 1) which is probably *G. triplex* Jungh., under *G. fimbriatum*. In his diagnosis of 1801, Persoon referred Schmidel's figures to a '*Var. minor colore dilutiore*'. Persoon (1809) only cited the two plates of Schmidel and wrote: 'Ce Geastre est grand, ses rayons sont épais et s'étalent horizontalement ou ils se recourbent. L'ouverture du péridie est soyeuse; Schmiedel l'a fait figurer dentelée. Le nom spécifique en indique la couleur.'

Berkeley & Broome (1848) stated that an authentic specimen of *G. rufescens* from Persoon was identical with *G. fimbriatum* Fr., but that '*G. rufescens* Fr.' is quite a different thing; which is repeated by Berkeley (1860).

After his study of the Persoon specimens at Leiden, Lloyd (1904) wrote that *G. fimbriatum* is the most common European species, and has been known under that name since the days of Fries's *Systema*, but that it is *G. rufescens* of Persoon, according to all Persoon's specimens, although *G. rufescens* 'Persoon' has now acquired a different signification. He considered *G. fimbriatum* to be correctly named and that a shuffle of names would necessitate a 'new species' being described, although he had earlier (1902) given *G. schaefferi* Vitt. as a synonym of *G. rufescens*.

Van Waveren (1926) saw the Persoon material. He re-established the identity of *G. rufescens* Pers., reducing *G. fimbriatum* Fr. to synonymy and referring *G. rufescens* sensu Fr. *et aut. auct.* to *G. schaefferi* Vitt.

Van Eyndhoven (1937*a*) confirmed van Waveren's findings and designated as lectotype specimen *H.L.B. no.* 910,262–393 (*no.* 128 *zw.*) but, presumably due to a typographical error, the number is cited as '910,262–293 (no. 128 zw.)'.

Modern monographers of the Gasteromycetes, such as Coker & Couch (1928) and Cunningham (1944), have followed the erroneous tradition and treated *G. rufescens* Pers. as distinct from *G. fimbriatum*, with no reference to the papers of van Eyndhoven and van Waveren.

Discussion

Persoon's descriptions of *G. rufescens* and references to the figures of earlier authors make it plain that two species were covered by his taxon; i.e. *G. rufescens* sensu Fr. and *G. fimbriatum*. However, *G. fimbriatum* Fr., as traditionally understood, is much more common than *G. rufescens* sensu Fr., and, as five of the six specimens labelled '*G. rufescens*' among his exsiccati are this species, the remaining specimen being *Astraeus hygrometricus*, clearly the fungus on which Persoon based the name *Geastrum rufescens* was that later called *G. fimbriatum*. Van Waveren (1926) was therefore fully justified in redefining *G. rufescens* Pers. in the sense of Persoon's authentic material and reducing *G. fimbriatum* Fr. to synonymy. Van Waveren identified the false *G. rufescens* of later authors with *G. schaefferi* Vitt.

Van Eyndhoven (1937*b*) ascertained during his investigation of *G. schaefferi* that no type material of this species exists in the Vittadini Herbarium at Turin. Dr V. J. Staněk has pointed out to the writer that the description of *G. vulgatum* Vitt. fits the traditional *G. rufescens*, especially as regards colour, better than does that of *G. schaefferi*, although both probably refer to the same fungus. *G. vulgatum* was referred to *G. fimbriatum* by Fischer (1933). Petri (1909) stated that the type is in Saccardo's Herbarium. An examination, through the kindness of Prof. C. Cappelletti of Padua University, confirms Staněk's opinion and shows this material to consist of two small but otherwise typical specimens of *G. rufescens* sensu Fr.

Study of fresh British material

The fruiting-bodies of *G. rufescens* Pers. em. van Wav. form as globose structures (*eggs*) just below the surface of the substratum, varying up to 3 cm. diam., and are difficult to locate before expansion because of the debris-encrusted *mycelial layer* (Figs. 2*l–o*), although the eggs are basally attached. A section of an immature egg shows a white *gleba* with the *tramal plates* radiating outwards from a clavate *pseudo-columella* (Fig. 2*m*). *Basidia* develop as globose or clavate bodies, and from the apex of each grows an elongated clavate structure (*epibasidium*) upon which up to six (to eight?) spores develop on *sterigmata* on the upper part and sides of the club (Fig. 3*n–p*) with overall dimensions between 11 and 19 × 4 and 7 μ. Some time before expansion occurs, the *gleba* deliquesces and becomes a powdery brown mass of *spores* and *capillitium threads*. Under suitable conditions, the egg fissures into 5–12 usually wedge-shaped to acuminate *rays*, which become recurved at the tips but, at the centre, remain united in a shallow depression supporting the *endoperidium*, although occasional specimens are met which are not saccate but have strongly recurved *exoperidia*. Expanded specimens vary from 1 to 9 cm. in diam., although minute sporophores are frequently aborted. Material from Coed Pwll-y-blawd, Denbighshire, under *Pinus sylvestris* (J.T.P. 195), contained specimens which had fully expanded without the *exoperidium* fissuring into rays but remaining almost intact as a surrounding saccate structure. The fleshy layer is up to 2 mm. thick (to 3 mm. in robust specimens), and varies from whitish to a creamy pink, drying ochraceous to brown. This tissue tends to crack but rarely flakes away, and usually dries on the rays as an adnate layer but completely weathers away in exposed specimens. The *mycelial layer*, usually cream in colour, is generally obscured by debris, and, in old specimens, tends to separate from the rays, occasionally completely, to expose the shiny, creamy *fibrillose layer* which, with the *fleshy layer* weathered away, often assumes a characteristically thin, paper-like texture. In old specimens, the *exoperidium* is often found to have shrunk into a peculiar rim-like structure with the *endoperidium* seated within it and the ray tips recurving underneath the *peridium* and then turning outwards again (Fig. 2*x*). The *endoperidium*, generally some shade of fawn but sometimes darker and occasionally purplish, usually smooth and elongated to depressed globose in shape, is normally sessile. Occasionally, it is very shortly stipitate, especially in robust specimens. However, as with most geasters, a vertical section shows there to be a *pedicel* up to a few millimetres high which apparently shrinks during drying and rarely becomes obvious due to the method of attachment of the *endoperidium*. The *mouth* is indeterminate, although frequently lighter in colour than the *endoperidium*, with a rather shiny appearance, and varies from papillate to plane, whilst frequently torn and gaping in old specimens. The *gleba* is often a light snuff-brown but varies in shade. The *pseudo-columella* varies from narrowly clavate to occasionally bushy, typically with a thin, whitish core (Figs. 2*v*–*w*), and is formed of *capillitium threads*, which are also attached to the inner wall of the *endoperidium*. These threads are mainly coloured, aseptate structures varying from 750 to 2250 μ long, tapering to a blunt tip at each end about 1–3 μ diam., with thick walls and a visible lumen (Fig. 2*z*), up to 12 μ diam. The *spores* vary from 2 to 3 to 4 μ diam., with *exospore* 2–3·5–4·5 μ, coloured, 1-guttulate, subglobose to occasionally ellipsoid, with a finely warted, spiny or punctate ornamentation.

The species is reported from both coniferous and frondose woods, but the author has collected odd specimens on the open moss/lichen slacks on the Lancashire coast, where it is rather abundant in certain deciduous thickets. Here it seems to be particularly frequent in old nettle-beds (Palmer, 1952), and the prominent creamy mycelium can be observed ramifying throughout the substratum and amongst the roots for a depth of several inches.

Delimitation of the species

Key characters would appear to be (*a*) the indeterminate *mouth*, (*b*) small *spores*, (*c*) saccate *exoperidium*, (*d*) debris-encrusted *mycelial layer* which tends to peel away, sometimes completely, to expose the smooth, shiny and cream-coloured *fibrillose layer*, and (*e*) characteristic *basidia* with *spores* developing apically on a clavate *epibasidium*.

Geastrum rufescens Pers. often occurs with *G. triplex* Jungh., which may be distinguished by its usually larger size, determinate *mouth*, smooth brown *mycelial layer* free from debris with longitudinal fissures, *spore* size and ornamentation, *basidium* with a tapering *epibasidium* swelling apically into a *capitellum* which bears six (to eight?) *spores*, and epigeous development as a bulb-like *egg* with a prominent umbo. The accidental cup-like structure frequently assumed by the *fleshy layer*, and from which *G. triplex* received its name, does not seem to occur with *G. rufescens*.

G. vulgatum Vitt. (syn. *G. rufescens* Pers. sensu Fr.) is distinguished by its characteristic flesh-pink colour and larger *spores*, amongst other, less constant or prominent, characters. Extreme forms of both species are sometimes rather difficult to place.

No. 3. A note on geaster basidia

Previous taxonomic studies of *Geastrum* have been based mainly on desiccated material. For many species, no description of the freshly expanded state has been published, and for most of them the development of the fruit-body remains undescribed.

This lack of observation is probably due to the rarity of many species and the hypogeous development of most of them with deliquescence and maturation of the glebae before expansion.

Geastrum triplex Jungh.

This is about the most common British species. It has epigeous eggs, looking rather like onions (Fig. 3*a–d*), and occurs abundantly amongst leaf-mould in the thickets on the Lancashire dunes (Palmer, 1952) and, occasionally, in the sheltered hollows of the fixed dunes. The eggs are at first violaceous-pink, although later, apparently as the gleba starts to deliquesce, the exoperidium (mycelial layer) turns brown, becomes much tougher in texture and cracks into the longitudinal fissures so characteristic of the species (Fig. 3*c*) or, less often, breaks up into large scales.

An examination of a young, violaceous-pink egg showed a white gleba with the tramal plates radiating from the clavate pseudo-columella. Tissue was removed with mounted needles and teased out on a slide in Erythrosin B in 10% ammonia for examination.

Many basidia had discharged their spores and collapsed, but others were observed in various stages of development, varying from clavate (when forming) to skittle-shaped with capitate apices upon which the sterigmata formed, with the upper parts finally being obscured by clusters of spores (Fig. 3*e*).

The eggs appear in the thickets several months before expanded specimens are found. In the late summer and autumn of 1954, young eggs from six distinct localities on the Lancashire dunes were collected and their basidia examined. Four collections were made in mixed thickets dominated by *Acer pseudoplatanus*. One collection, which had expanded specimens differing from the typical form by the long, slender rays, and might have been referred to *Geastrum lageniforme* Vitt., had somewhat slender basidia (Fig. 3*k*) and came from a thicket of *Syringa vulgaris*. Another collection, from a plantation where *Pinus sylvestris* predominated, had much larger, thick-walled basidia with the capitella almost sessile (Fig. 3*i*). Eggs from the *Acer pseudoplatanus* thicket at Blundellsands were large, squat structures with tall, slender basidia (Fig. 3*h*). It was not possible to locate eggs in the dune hollows where, no doubt due to the constant depositing of wind-borne sand, they are usually deeply immersed.

J.T.P. 68 (Fig. 3*e*). Amongst leaf-mould in *A. pseudoplatanus* thicket, Formby Hills, Freshfield, Lancs., 1 November 1951. *Basidia* 15–20 × 5·5–9μ. At first globose to clavate, developing apically an *epibasidium*, the tip of which swells into a globular, knob-like structure (*capitellum*) upon which the *sterigmata* appear, usually two apical and four lateral at the cardinal points, with the *spores* forming on them and gradually enlarging until the

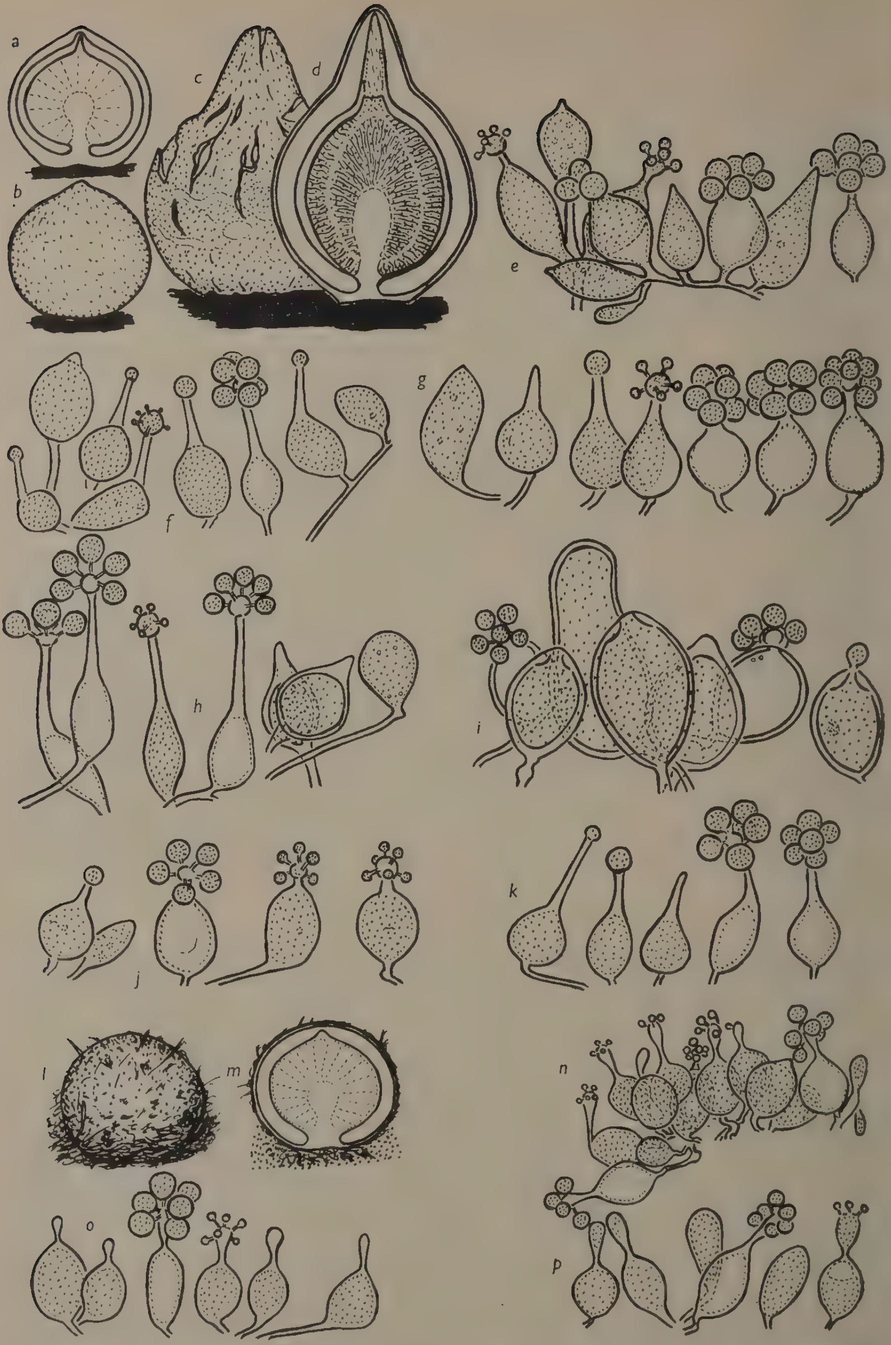

Fig. 3. *a–k*, *Geastrum triplex* Jungh. *a*, vertical section of egg showing immature gleba. × 1. *b*, young violaceous-pink egg. × 1. *c*, egg shortly before expansion. × 1. *d*, vertical section of same showing matured gleba. × 1. *e–k*, basidia in various stages. × 1000. *e*, J.T.P. 68; *f*, J.T.P. 68*a*; *g*, J.T.P. 106*c*; *h*, J.T.P. 123*a*; *i*, J.T.P. 292; *j*, J.T.P. 308; *k*, J.T.P. 309. *l–p*, *Geastrum rufescens* Pers. em. van Wav. *l*, unexpanded egg. × 1. *m*, vertical section of same showing immature gleba. × 1. *n–p*, basidia in various stages, × 1000. (*n*, J.T.P. 87*a*; *o*, J.T.P. 87b; *p*, J.T.P. 343.)

whole upper structure of the *basidium* is obscured by a cluster of *spores*, usually six. *Eggs* up to 3·5 cm. diam., subglobose. Agreed well with normal form of the species.

J.T.P. 68*a* (Fig. 3*f*). Habitat as for J.T.P. 68, 17 July 1954. *Basidia* 13·5–19 × 5·5–7·5 μ. At first globose, *epibasidium* development similar to J.T.P. 68 with six (to eight?) *spores*. *Eggs* up to 3 cm. diam. with a prominent beak. Agreed with normal form.

J.T.P. 106*c* (Fig. 3*g*). Amongst leaf-mould in mixed thicket (*Acer pseudoplatanus*, *Alnus glutinosa* and *Populus* sp.), Formby Hills, Freshfield, Lancs. (approximately ¾ mile from J.T.P. 68), 17 July 1954. *Basidia* 13·5–19 × 6–8 μ. At first globose to clavate with similar development to foregoing but with *epibasidium* more broadly tapering. *Eggs* approximately 3 cm. diam., usually shortly umbonate, although specimen examined for *basidia* was globose (umbo not developed?). Expanded specimens agreed well with normal form.

J.T.P. 123*a* (Fig. 3*h*). Amongst leaf-mould in *Acer pseudoplatanus* thicket, Merrilocks Plantation, Blundellsands, Lancs., (approximately 5¼ miles from J.T.P. 68), 31 July 1954. *Basidia* 25–27 × 4·5–5 μ. At first globose, thick-walled, elongating into a tall, slender *epibasidium* with *spores* forming in the usual way. *Eggs* up to 5 cm. diam., depressed globose. Expanded forms frequently luxuriant, otherwise as for normal form.

J.T.P. 292 (Fig. 3*i*). Amongst needle litter in plantation with *Pinus sylvestris* predominating, Raven Meols Hills, Formby, Lancs. (about 1¼ miles from J.T.P. 68), 31 July 1954. *Basidia* 14–19 × 8–13 μ. Differed from all other specimens examined by the larger, thickwalled *basidium* and short, almost obsolete *epibasidium* with the *capitellum* frequently nearly sessile. Mainly six-spored. *Eggs* up to 4·5 × 3·5 cm., elongated-globose with apical umbo. No expanded material was collected and the writer was unable to locate the exact habitat afterwards.

J.T.P. 308 (Fig. 3*j*). Under *A. pseudoplatanus* in hedgerow, Kirklake Road, Formby, Lancs. (about 1 mile from J.T.P. 68), 28 August 1954. *Basidia* 13·5–16 × 7–8 μ. At first clavate to globose, elongating into a short *epibasidium* not dissimilar to J.T.P. 292. Eggs up to 2·5 cm. diam.. globose. Expanded specimens agreed with normal form.

J.T.P. 309 (Fig. 3*k*). Amongst leaf-mould in *Syringa vulgaris* thicket, Raven Meols Hills, Formby, Lancs. (about 1½ miles from J.T.P. 68), 31 July 1954. *Basidia* 14–21·5 × 5·5–7·5 μ. At first globose, elongating apically into a long, slender *epibasidium*, but not as tall as J.T.P. 123*a*. Eggs up to 3 cm. diam., with a very prominent umbo. Expanded specimens with long, narrowly acuminate *Rays*, twisting up when dry.

Geastrum rufescens Pers. em. van Wav.

This species occurs abundantly with *G. triplex*, although more inclined to old nettle-beds and sloping banks, in the same mixed thicket at Freshfield, Lancs., as J.T.P. 106*c*. It develops hypogeously and thus the eggs are difficult to locate. A careful forking over of the substratum in the neighbourhood of expanded specimens produced several globose, debris-encrusted eggs (Fig. 3*l–m*). On sectioning, the *gleba* was found to be still white and immature. Tissue was teased out in Erythrosin B in 10% ammonia similarly to *G. triplex*.

An examination showed abundant basidia which, whilst bearing some resemblance to those of *G. triplex*, differed by the epibasidium being clavate with sterigmata forming apically and, occasionally, on the upper sides instead of on a capitellum (Fig. 3*n*).

Whilst this species has been collected on other parts of the Lancashire dunes, although much less common than *G. triplex*, and under both *Fagus sylvatica* and *Pinus sylvestris* at Coed Pwll-y-blawd, Denbighshire, collections have been sparse or old and no eggs located. However, basidia were observed and drawn from collections made in 1953 and 1954, whilst an egg in a collection from the Gog Magog Hills, near Cambridge, contained basidia.

J.T.P. 87*a* (Fig. 3*n*). Amongst leaf-mould in old nettle-bed, mixed thicket (*Acer pseudoplatanus*, *Alnus glutinosa* and *Populus* sp. with *Pinus nigra* adjacent), Formby Hills, Freshfield, Lancs., 29 August 1953. *Basidia* 11–13·5 × 5·5–7 μ. At first globose or clavate, apically elongating into a clavate *epibasidium* with *sterigmata* forming on the top and upper sides with clavum eventually obscured by fully developed *spores*, four to six (eight?) in number. *Eggs* up to 3 cm. diam., globular, usually immersed in substratum but sometimes slightly protruding. Expanded specimens agreed well with the normal form.

J.T.P. 87*b* (Fig. 3*o*). Habitat as for J.T.P. 87*a*, 28 August 1954. *Basidia* 11–19 × 4–7 μ. Similar basidial structure to J.T.P. 87*a* with occasional 'triangular' forms. Expanded material agreeing well with normal form.

J.T.P. 343 (Fig. 3*p*). Amongst mixed *Fagus sylvatica* and *Acer pseudoplatanus* leaf-mould (adhering to specimens) on chalk under *Larix europaea* in wood near the Roman Road, Gog Magog Hills, Cambridgeshire, 1 October 1954, leg. H. M. Parker. *Basidia* 13·5–18 × 5–6 μ. At first clavate to globose, elongating into a broadly clavate *epibasidium* with *sterigmata* (four to six) apical to lateral. *Eggs* up to 3 cm. diam., globular with slight umbo. Expanded specimens agreeing with normal form.

Literature

Basidia of species of *Geastrum* have been described by several authors, but the published data remain somewhat scattered and incomplete.

The Tulasnes (1842) studied material which they referred to *G. rufescens* Fr. and *G. fimbriatum* Fr. Regarding *G. rufescens*, they wrote: 'Les basides qui tapissent les parois des locules fructifères terminent les filamens de la trame et sont d'un bien plus grand diamètre. Celles du *G. rufescens* sont quelquefois partagées par des diaphragmes, ce qui ferait supposer qu'elles ne seraient pas toujours uniquement dues à la dilatation de la cellule extrême d'un filament, mais que plusieurs cellules terminales, dont les parois communes se détruiraient, concourraient dans certains cas à leur formation.' Their pl. 6, figs. 13–15, shows basidia varying from globose or clavate to broadly ovate or, in some cases, obovate, with two to four apical sterigmatic spores and most basidia containing two large vacuoles. For

G. fimbriatum, pl. 5, fig. 11*a*, captioned: 'Cellules qui doivent porter les spores', shows branching hyphae terminated by globose to clavate bodies, presumably immature basidia.

They also treat *Astraeus hygrometricus* (Pers.) Morg. (as *Geaster hygrometricus* Pers.), which has the normal form of basidium. *Astraeus* has been made the type of a new family by some authors, hence it is not proposed to deal with it here, although both Cunningham (1944) and Bottomley (1948) retain the species in *Geastrum*.

Costantin & Dufour (1891, pl. 55, fig. 1718) show under *G. rufescens* Pers. a figure similar to Vittadini (1843), tab. I, fig. 1, of *G. schaefferi* Vitt. They figure an obclavate basidium closely resembling the Tulasnes's (1842) figures, as do their basidia of both *G. fimbriatum* (fig. 1711 ba—immature) and *A. hygrometricus* (fig. 1710 ba).

Maire (1900) made a cytological study of the Gasteromycetes and described basidia with clavate epibasidia bearing two to eight spores, which he attributed to *A. hygrometricus*. He considered the epibasidium to be a compound sterigma, although he observed that the spores were borne on very short pedicels.

Maire (1902) corrected the determination to *G. fimbriatum* Fr. (= *G. rufescens* Pers. em. van Wav.). His drawings of basidia (pl. VI, figs. 36–42) show various development stages which agree well with the basidia of *G. rufescens* Pers. em. van Wav. observed by the writer (Fig. 3*n*–*p*). He gave a detailed description of the formation of from two to eight spores and wrote: 'Quoi qu'il en soit, chez notre *Geaster*, la formation des spores se fait de la façon suivante: au sommet de la baside pousse un *prolongement unique*, sorte de *stérigmate collectif*, au sommet duquel se forment les spores sur des pédicules très courts. Les noyaux, en nombre définitif, s'engagent tous ensemble en s'étirant dans la stérigmate commun, pour se rendre ensuite séparément chacun dans sa spore. Pour passer dans le stérigmate commun et dans les petits stérigmates particuliers, le noyau se transforme comme d'habitude en une masse chromatique homogène, fortement basophile.

'Arrivé dans la spore, le noyau y subit une mitose; la spore mûre, dont la membrane est épaissie, cutinisée, contient deux noyaux très petits.'

Lloyd (1902*b*, fig. 7*b*) reproduced one of the Tulasnes's figures referred to *G. rufescens* Fr. W. G. Smith (1908, fig. 130*o*) depicted an obclavate basidium with four distinct, apical, sterigmatic spores, which he attributed to *G. rufescens* Pers. Swanton (1909) showed a similar structure which he referred to a '*Geaster* sp.'.

Cunningham (1927) made a study of the epigean *G. velutinum* Morg., apparently very common in New Zealand, taking twelve development stages. He observed that, shortly after the differentiation of the *fleshy layer* began, a dome of lacunae appeared between it and, partially surrounding, the *Pseudocolumella*. The lacunae soon became lined with inflated cells much larger than the surrounding hyphae, which were really basidia, but he called them '*primary basidia*' to distinguish them from those produced at a later stage. These structures were irregular in size and shape, and arose directly from the modified portions of the hyphae of the *tramal plates*. Many were monosporous but they soon became more regular in form and bore several spores (usually four at that stage) on short sterigmata. Development continued and, as each basidium matured, it produced four to eight spores, which became detached when the basidium collapsed. He wrote: 'Owing to this rapid development of basidia, the plates become thinner and more lamellar, a change accompanied by a decrease in the size of the basidia. Decrease in size is rapid, so that shortly after spore production has begun the basidia are seen to be less than one fourth the dimensions of the primary basidia. The smaller ones, which are responsible for the greatest spore production, are here termed secondary basidia (fig. 9). They are usually four-spored, but eight-spored forms are not uncommon.... Spore production begins when the plants are 7–8 mm. in diam., and continues uninterruptedly until the tramal plates break up.' His illustrations show (fig. 8) broadly clavate to sack-shaped primary basidia bearing one to four sterigmatic spores and (fig. 9) irregularly clavate secondary basidia bearing up to eight sterigmatic spores growing on both sides of a section of a tramal plate. Whilst some basidia are apparently growing directly from the tramal plate, others appear to be separated from it by one to two cells.

N. J. G. Smith (1935) stated that, in his study of the eggs of *G. saccatum* Fr., which is considered to be closely related to *G. triplex*, whilst four spores was the usual number, up to eight could be found. His fig. 2 shows a hymenium with a single row of simple clavate to sack-shaped basidia bearing from two to five sterigmatic spores.

So far as can be ascertained, no other observations have been published on these structures. Lohwag (1929) studied *G. triplex* but, although he illustrates an egg, made no mention of basidia. Martin (1938) discussed the literature on basidia but did not seem to have been aware of these forms.

Discussion

The presence of characteristic basidia in different species of *Geastrum* may be of primary importance both as regards establishing a natural relationship within the genus and distinguishing between critical taxa.

Several attempts have been made to arrange the group naturally using such morphological characters as mouth structure, separation of exoperidial layers, etc., but all the proposed arrangements are inconsistent in some respects.

Unfortunately, the use of basidia for distinguishing between critical species could only be made where developing fruit-bodies were sufficiently abundant in the field.

In his study of *Geastrum* from all parts of the globe, Lloyd (1907) seems to have experienced considerable difficulty in separating *G. triplex* from *G. saccatum*, which he resolved by the criterion of size.

Although an exhaustive study has not been made, examination shows that basidia from specimens which would be attributed to *G. triplex* on morphological characters, whilst showing quite a variation in size and shape, do conform to a certain type of structure: a globose to clavate basidium elongating at the apex into a tapering epibasidium of varying length with the apical formation of a knob (capitellum) on which spores are produced on sterigmata, usually two apical and four laterally situated at the cardinal points, although up to eight spores have been counted in the cluster on a fully developed basidium.

Specimens for the study were collected within a six-mile strip of the south Lancashire coast. It was not possible to examine material from a wider area, and eggs received from correspondents had matured glebae.

From studies by Cunningham (1927) and N. J. G. Smith (1935) the apparently closely related *G. velutinum* Morg. (New Zealand) and *G. saccatum* Fr. (South Africa) would seem to have basidia more in conformity with the Homobasidiomycetes, although Cunningham reported both primary and secondary basidia in *G. velutinum*, with the latter diminishing rapidly in size to less than one quarter of the former, and both workers observed up to eight spores.

Whilst development stages have not been studied, basidia were examined at intervals from individual eggs during the period between sectioning and full deliquescence of the gleba. Only the expected size variation was seen with no diminution, as reported by Cunningham (1927).

Specimens of *G. rufescens* Pers. em. van Wav. (syn. *G. fimbriatum* Fr.), although fewer in number, came from two widely separated places. The basidia showed a different, although not altogether dissimilar, structure to *G. triplex*: a globose to clavate basidium elongating into a clavate epibasidium with four to six (to eight?) spores, usually arranged apically, but sometimes on the upper sides of the epibasidium.

As the species develops below ground, its eggs are much more difficult to locate than those of *G. triplex*, being immersed in the substratum and debris-encrusted.

The basidia have already been noticed in literature (Maire, 1900, 1902), although they were at first erroneously attributed to *Astraeus hygrometricus*. It seems remarkable that his observations did not spur on somebody to make further examinations of these structures.

The only other geaster basidia observed in literature have been attributed to *Geastrum rufescens* sensu Fr., presumably *G. vulgatum* Vitt., and are of the typical Homobasidiomycete form. During the present study, the eggs of *G. vulgatum* have been sought in turf on a scrub-covered hillside in Derbyshire, where the species occurs in reasonable abundance and, whilst several eggs were successfully located during 1954, they all proved to be either too young or too old. Confirmation of the Tulasnes's observations on the basidia of *G. vulgatum* would provide a valuable character for differentiating between those extreme forms of *G. rufescens* Pers. em. van Wav. and this species which appear to overlap as regards gross morphology.

REFERENCES

Berkeley, M. J. (1860). *Outlines of British fungology*. London.

Berkeley, M. J. & Broome, C. E. (1848). Notices of British Fungi, No. 378. *Geaster rufescens* P. *Ann. Mag. Nat. Hist.*, Ser. 2, **2**, 268.

Bottomley, A. M. (1948). Gasteromycetes of South Africa. *Bothalia*, **4**, 473–810.

Coker, W. C. & Couch, J. N. (1928). *The Gasteromycetes of the Eastern United States and Canada*. Chapel Hill.

Costantin, M. J. & Dufour, M. L. (1891). *Nouvelle flore des Champignons*. Paris.

Cunningham, G. H. (1926). The Gasteromycetes of Australasia. IV. Species of the genus *Geaster*. *Proc. Linn. Soc. N.S. Wales*. **51**, 72–93.

Cunningham, G. H. (1927). The development of *Geaster velutinus*. *Trans. Brit. mycol. Soc.* **12**, 12–20.

Cunningham, G. H. (1944). *The Gasteromycetes of Australia and New Zealand.* Dunedin.

Fischer, Ed. (1933). *Die natürlichen Pflanzenfamilien.* 7a. Leipzig.

Fries, E. M. (1829). *Systema mycologicum*, **3**. Gryphiswaldae.

Hollós, L. (1904). *Die Gasteromyceten Ungarns.* Leipzig.

Lloyd, C. G. (1902*a*). The Geastrae. *Bull. no.* 5. *Mycol. Ser.* no. 2, Cincinnati.

Lloyd, C. G. (1902*b*). *The genera of Gastromycetes.* Cincinnati.

Lloyd, C. G. (1903). Note 252. *Geaster floriformis. Mycol. Notes*, no. 14. Cincinnati.

Lloyd, C. G. (1904). Note 281. Historical Notes. *Mycol. Notes*, no. 17. Cincinnati.

Lloyd, C. G. (1907). New notes on the Geasters. *Mycol. Notes*, no. 25. Cincinnati.

Lohwag, H. (1929). Mykologische Studien. II. *Geaster triplex* Jungh. *Arch. Protistenk.* **65**, 65–77.

Long, W. H. & Stouffer, D. J. (1948). Studies in the Gasteromycetes. XVI. The Geastraceae of the South-West United States. *Mycologia*, **40**, 547–585.

Maire, R. (1900). Sur la cytologie des Gastromycètes. *C.R. Acad. Sci., Paris*, **131**, 1246–1248.

Maire, R. (1902). Recherches cytologiques et taxonomiques sur les Basidiomycetès. *Bull. Soc. myc. Fr.* **18**, Supplement.

Martin, G. W. (1938). The morphology of the basidium. *Amer. J. Bot.* **25**, 682–685.

Micheli, P. A. (1729). *Nova plantarum genera.* Florentiae.

Morgan, A. P. (1887). The genus *Geaster*. *Amer. Nat.* **21**, 1026–1029.

Palmer, J. T. (1952). Lancashire and Cheshire earth-stars. *Proc. Lpool Nat. Fld Cl.*, pp. 28–31.

Persoon, C. H. (1801). *Synopsis methodica fungorum.* Göttingiae.

Persoon, C. H. (1809). Mémoire sur les Vesse-Loups ou *Lycoperdon*. *Desv. J. Bot.* **2**, 5–31.

Petri, L. (1909). *Gasterales* in *Flora Italica Cryptogama*, **1**.

Schaeffer, J. C. (1762). *Fungorum qui in Bavaria et Palatinate etc.* Ratisbonae.

Schmidel, C. C. (1782). *Icones plantarum et analyses partium.*

Smith, N. J. G. (1935). Notes on *Geaster* with special reference to the Eastern Cape. *Rec. Albany Mus., Grahamstown (S.A.)*, **4**, 256–282.

Smith, W. G. (1908). *Synopsis of the British Basidiomycetes.* London.

Staněk, V. J. (1953). Rehabilitace hvězdovky uherskě-*Geastrum hungaricum* (Hollós 1901) V. J. Staněk 1952 a její výskyt v ČSR. *Česká mykologie*, **7**, 34–42.

Swanton, E. W. (1909). *Fungi and how to know them.*

Tulasne, L. R. & Tulasne, C. (1842). Sur les genres *Polysaccum* et *Geaster*. *Ann. sci. nat.* ser. 2, **18**, *Bot.*, 129–141.

van Eyndhoven, G. L. (1937*a*). Geastrologische Notizen: 2. Die Typen von *Geastrum rufescens* Persoon (syn. *G. fimbriatum* Fries) und *Geastrum quadrifidum* Persoon (p.p.) (syn. *G. coronatum* (Schaeffer) Schroeter) im Herbarium Persoon. *Med. ned. mycol. Ver.* **24**, 13–14.

van Eyndhoven, G. L. (1937*b*). Geastrologische Notizen: 3. Die Frage des Vorkommens von *Geastrum Schaefferi* Vitt. in den Niederlanden. *Med. ned. mycol. Ver.* **24**, 14.

van Waveren, E. Kits (1926). De Nederlandsche Soorten der Genera *Geaster*, *Myriostoma* en *Astraeus*. *Med. ned. mycol. Ver.* **15**, 85–129.

Vittadini, C. (1843). Monographia Lycoperdineorum. *Mem. Ac. Torino*, Ser. 2, **5**, 145–237. (Published separately 1842.)

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Trans. Brit. mycol. Soc. **38** (4), 335–346 (1955).

SURVIVAL AND RECOLONIZATION BY FUNGI IN SOIL TREATED WITH FORMALIN OR CARBON DISULPHIDE

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(With 3 Text-figures)

In samples of soil taken 3 weeks after treatment with dilute formalin (1:500 to 1:1000), *Trichoderma viride* had established itself as the dominant fungus, and this dominance persisted during the 6 months period of sampling. On agar, *T. viride* was more tolerant of formalin than were seven other common soil fungi. *T. viride* also became dominant after treatment of soil with carbon disulphide, at the rate of 0·5 ml./250 g. moist soil. After higher dosages (1 to 10 ml. carbon disulphide), the dominant fungi were two Ascomycetes, *Penicillium luteum* and *Aspergillus fischerii*, which were found to be highly tolerant of carbon disulphide *in vitro*, by comparison with other fungi tested.

Recolonization of soil sterilized, by intermittent steaming, from an inoculum of unsterilized soil was followed by means of the 'soil recolonization tube', which comprises an 18 in. length of tube with seven side-arms at 2 in. intervals. From the side-arms, which were protected from outside contamination by metal caps, micro-samples of soil were taken at intervals for the making of soil plates, and in this way the progress of soil colonization by fungi along the length of the main tube could be followed. In closely packed soil, the first fungal colonizers were fast-growing Phycomycetes, but in loosely packed soil, their place was usually taken by *Trichoderma viride*.

Soil recolonization tubes were also used to study the movement of formalin and carbon disulphide, respectively, through the soil. Distribution of the fumigant, which was injected at the central side-arm, was determined after an interval by taking samples of soil for plating from the side-arms on either side of it.

INTRODUCTION

The work to be described in this paper was in continuation of that carried out in this laboratory by Warcup (1951*b*, 1952) who found that whereas soil treated with steam was recolonized by a comparatively diverse flora of fungi, that treated with formalin was recolonized by fewer species, amongst which *Trichoderma viride* was dominant. Owing to the fact that some strains of *T. viride* are known to produce one or other of the two antibiotics, gliotoxin and viridin (Brian, 1951), this dominance of *T. viride* in formalin-treated soil was of particular interest, in so far as it might help to control the activity of re-invading root disease fungi. This possibility was emphasized by Bliss (1951), who produced evidence in support of his hypothesis that soil fumigation with carbon disulphide, at the concentrations normally used in Californian citrus orchards, is not directly lethal to *Armillaria mellea* in infected citrus roots. Thus *A. mellea* was not killed when

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fumigated with carbon disulphide in previously sterilized soil; when fumigated in unsterilized soil, the death of this fungus in the infected roots did not occur completely and at once, but was brought about gradually over a period of some 3 weeks. Through the observation that *Trichoderma viride* was regularly isolated from those pieces of root in which *Armillaria mellea* was no longer viable, Bliss was led to the conclusion that *Trichoderma viride* was responsible for the death of *Armillaria mellea*. He supposed that fumigation of the soil with carbon disulphide led to a dominance in the new fungus flora of *Trichoderma viride* which was able to break through the pseudosclerotial wall of *Armillaria mellea* within the infected root tissue, and then to kill the mycelium within. Bliss showed that *A. mellea* in infected roots was quickly killed if buried in soil that had been completely sterilized and then re-inoculated with *Trichoderma viride*.

The purpose of the present investigation was to study in greater detail the composition of the new fungus flora developing in soils treated with different concentrations of formalin or carbon disulphide. The recolonization of completely sterilized soil from outside was followed by means of a new device designated as the 'soil recolonization tube' (Evans, 1954*a*). This apparatus proved equally useful for studying the movement of fumigants and other sterilizing agents in soil, as revealed by their microbiological effects on the soil microflora.

Methods

Only one type of soil was used for this work—Kettering loam, which is one of the stock soils used at the Cambridge Botany School, and was also employed for part of Warcup's (1952) work. In texture this soil is a medium loam, with pH value 6; organic matter and total nitrogen contents are somewhat high, whereas available potash and phosphate are rather low. The moisture-holding capacity (hereafter designated as the M.H.C.) was determined as 66 ml. water per 100 g. air-dry soil, and this reflects the somewhat high organic content.

For the purpose of the work to be described, the fungus flora of Kettering loam was studied in considerable taxonomic detail (Evans, 1954*b*). All determinations of the fungus flora in variously treated samples of soil were made by means of the Warcup soil plate (Warcup, 1950), which will be referred to as the 'soil plate'. Owing to the large number of soil plates that had to be examined it was not practicable to record the presence of every fungus colony growing on all the plates. Only the common fungi, therefore, were recorded. Fungi of limited growth, such as species of *Penicillium*, *Aspergillus*, *Fusarium* and *Gliocladium*, were usually scored conventionally as 1 % of the plate area for each colony. With more diffusely growing species, such as *Trichoderma viride* and members of the Mucoraceae, the percentage area of the plate covered by the fungus was estimated. Soil plates were prepared from all soil samples at least in triplicate, and recordings were made on the 5th and 7th days of incubation.

Other details of technique used in this work will be described as they occur, but a description of the *soil recolonization tube* is best given here. A difficulty common to all earlier work on recolonization of sterilized soil has been that of taking samples of soil for determination of the recolonizing micro-organisms. If the soil has been treated *in situ* in the field, it has been necessary to dig profile pits from the sides of which samples could be taken. If the soil has been treated in laboratory containers, then it has been necessary to sacrifice one container for each series of samples taken, and this has made it impossible to make consecutive observations on the soil in a single container. Furthermore, the disturbance consequent upon removal of soil before taking a sample much increased the likelihood of contamination by adventitious micro-organisms. The soil recolonization tube, which was designed to overcome these difficulties, consists of an 18 in. length of 'Pyrex' glass tubing, of 1 in. internal diameter, to which seven side-arms, 1 in. long and 0·5 in. internal diameter, are fused at 2 in. intervals (Fig. 1).

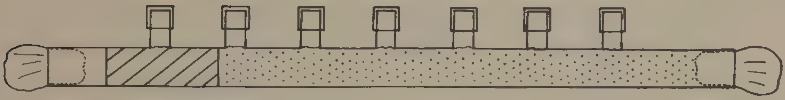

Fig. 1. The soil recolonization tube. Key: hatched, non-sterile inoculum; stippled, sterile soil.

Experiments have been conducted with duplicate or triplicate tubes for each soil treatment. The tubes were filled with soil previously passed through a 4 mm. sieve and adjusted to the required moisture content; even packing was obtained by tamping after each addition of 25 g. moist soil. For the purpose of soil recolonization studies, the ends of the main tube were plugged with cotton-wool, and those of the side-arms were covered with 'Oxoid' metal caps. For work on recolonization of steam-sterilized soil, the tubes were wrapped in grease-proof paper and sterilized by steaming for 1 hr. on 3 consecutive days. They were then inoculated with a substantial quantity of unsterilized soil placed at one end of the main tube (see Fig. 1) and thereafter weighed. Loss of water due to evaporation was periodically restored by weighing and adding sterile distilled water through the side-arms, starting at the one farthest from the inoculum. At suitable intervals, samples of soil were taken from the side-arms with a sterile microspatula, and from them soil plates were prepared for determination of the fungus flora.

For the purpose of studying the distribution of formalin or carbon disulphide in soil, the ends of the main tube and of the side-arms were sealed with rubber bungs after the apparatus had been filled with soil at the desired moisture content. The fungicide was then introduced through the centre side-arm and the apparatus resealed for the desired period (usually 24 hr.). After this, the rubber bungs were removed and replaced either by cotton-wool plugs or by 'Oxoid' metal caps. At intervals the distribution of the fungicide was ascertained by making soil plates from micro-samples taken from the side-arms, and comparing them with other soil plates made from the untreated control soil.

THE FUNGUS FLORA DEVELOPING AFTER SOIL TREATMENT WITH FORMALIN

Experiment 1. To 20 g. of soil adjusted to a moisture content of 30 % M.H.C. was added 7·5 ml. dilute formalin, giving a final moisture content of 84 % M.H.C. in the treated soil. Triplicate samples of soil were treated in boiling tubes with each of the following dilutions of formalin: 1:500, 1:750, 1:1000, 1:1500, 1:2000 and 0 (water, as control). The tubes were then plugged with cotton-wool, and stored at laboratory temperature for 3 weeks, which was found after preliminary trials to be a suitable period of incubation before taking samples of soil for the making of soil plates. The fungus flora developing on the soil plates is shown in Fig. 2. The soil was maintained in the plugged tubes for a period of 6 months, during which it was occasionally sampled, but over this period the various fungus floras persisted with little change.

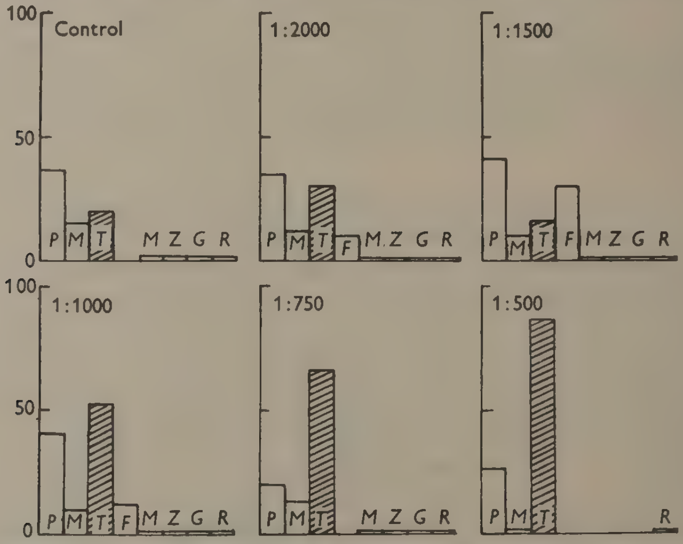

Fig. 2. The effect of various concentrations of formalin on the fungal flora of soil. Key: *P*, Penicillia; *M*, Mucoraceae; *T*, *Trichoderma viride*; *F*, Fusaria; *G*, *Gliocladium roseum*; *M*, *Mucor spinosus*; *R*, *Rhizopus stolonifer*; *Z*, *Zygorrhynchus vuilleminii.*

From Fig. 2 it is evident, as Warcup (1951*b*, 1952) also found, that *T. viride* is more tolerant of formalin than are other common soil fungi. Increasing concentrations of formalin appeared to eliminate successively the Fusaria, *Gliocladium roseum*, *Mucor spinosus*, *Zygorrhynchus vuilleminii* and finally *Rhizopus stolonifer* and *Penicillium citrinum.* In preliminary trials *Trichoderma viride* was the only fungus isolated from Kettering loam treated with formalin at concentrations of 1:10 and 1:50; the maximum concentrations of formalin treatment after which various fungi could be isolated from this soil are given in Table 1. Also shown in Table 1, for comparison, are the maximum concentrations of formalin in 3 % malt agar which would permit growth from a combined inoculum of spores and mycelium taken from pure cultures of the same fungi.

Amongst the common soil fungi tested, *T. viride* is outstanding in its tolerance of formalin both in soil and in agar culture. Whereas the trials in soil tested the minimum *fungicidal* concentration of formalin, that in agar tested the *fungistatic* concentration, and this fact explains the apparently lower tolerance of all the fungi to formalin in agar than in soil, apart from other obvious differences in the conditions of the two trials. A similar discrepancy between results of tests with a number of fumigants in soil and in agar has been noted by Jacks & Smith (1952).

Table 1. *Maximum concentrations of formalin tolerated by soil fungi in soil and in agar culture*

	In soil	On agar
Trichoderma viride	1:10	1:500*
Rhizopus stolonifer	1:500	1:2000
Penicillium citrinum	1:500	1:5000
Gliocladium roseum	1:750	1:2000
Zygorrhynchus vuilleminii	1:750	1:5000
Mucor spinosus	1:750	—
Fusarium culmorum	1:1000	1:5000
F. caeruleum	1:1000	—

* Maximum concentration of formalin tested in agar.

THE FUNGUS FLORA DEVELOPING AFTER SOIL TREATMENT WITH CARBON DISULPHIDE

Experiment 1. Aliquots of 250 g. of soil adjusted to a moisture content of 30 % M.H.C. were treated with carbon disulphide in glass containers fitted with metal lids and gas-tight rubber seals. A measured volume of carbon disulphide was introduced from a pipette through a glass tube into the bottom layer of soil in each container. The glass tube was then withdrawn from the soil, the space was closed by tapping the container on the bench, and the gas-tight lid was secured and left in place for a period of 24 hr. at laboratory temperature. At the end of this treatment period, lids were removed from the containers, and the fumigant allowed to disperse. Three containers of soil were treated with each of the following volumes of liquid carbon disulphide: 0·5, 1, 2, 4, 6, 8 and 10 ml. Through an unfortunate error, 10 ml. sterile water was added to the control containers of untreated soil, but this is not thought likely to have affected the results in any important respect. Samples of soil were taken from all containers 24 hr. after the end of the treatment period, and again after 10 days, as follows: a sterilized no. 1 size (4 mm.) cork borer was pushed down to the bottom of the container, and a cylinder of soil removed. The bottom 1·25 cm. of this cylinder of soil was then pushed out from the cork borer by means of a glass rod, and, from this sample of soil, microsamples were taken for preparation of soil plates. Fungi developing on the soil plates are shown in Table 2 (24 hr. samples) and Table 3 (10-day samples).

In Tables 2 and 3, it can be seen that after treatment of soil with the lowest dose of carbon disulphide tested, *T. viride* was the dominant fungus developing on the soil plates, both from the samples taken after 24 hr. and after 10 days. In the 24 hr. samples, plates made from soil treated with larger doses of carbon disulphide than 0·5 ml. were mainly colonized by

Table 2. *Fungal populations 24 hr. after treatment of soil with carbon disulphide*

Quantity of carbon disulphide per container (ml.)	Replicate soil containers					
	A		B		C	
		%		%		%
0	*T. viride*	10	*T. viride*	15	*T. viride*	5
	P. citrinum	22	*P. citrinum*	24	*P. citrinum*	17
	Mucoraceae	28	Mucoraceae	30	Mucoraceae	35
0·5	*T. viride*	50	*T. viride*	75	*T. viride*	75
	P. citrinum	5	*P. citrinum*	1	*P. citrinum*	4
1	*P. citrinum*	2	*P. citrinum*	4	Bacteria	—
	Bacteria	—	*R. stolonifer*	1	—	—
	—	—	Bacteria	—	—	—
2	Bacteria	—	Bacteria	—	Bacteria	—
4	Bacteria	—	Bacteria	—	Bacteria	—
	—	—	—	—	*R. stolonifer*	2
6	Bacteria	—	Bacteria	—	Bacteria	—
	R. stolonifer	2	—	—	—	—
8	Bacteria	—	Bacteria	—	Bacteria	—
	—	—	*R. stolonifer*	—	—	—
10	Bacteria	—	Bacteria	—	—	—

Table 3. *Fungal populations 10 days after treatment of soil with carbon disulphide*

Quantity of carbon disulphide per container (ml.)	Replicate soil containers					
	A		B		C	
		%		%		%
0	*P. citrinum*	22	*T. viride*	5	*P. citrinum*	29
	T. viride	10	*P. citrinum*	19	*T. viride*	5
	Mucoraceae	25	Mucoraceae	30	Mucoraceae	32
	G. roseum	5	*G. roseum*	5	*G. roseum*	4
	Fusaria	5	Fusaria	4	Fusaria	0
0·5	*T. viride*	50	*T. viride*	40	*T. viride*	35
	P. citrinum	14	*P. citrinum*	19	*P. citrinum*	40
	P. luteum	1	—	—	*P. luteum*	9
1	*P. luteum*	40	*P. luteum*	1	*P. luteum*	5
	A. fischerii	35	*A. fischerii*	14	*A. fischerii*	1
2	*P. luteum*	3	*P. luteum*	5	*P. citrinum*	15
	A. fischerii	56	*A. fischerii*	26	*A. fischerii*	15
4	*P. luteum*	26	*P. luteum*	3	*P. luteum*	6
	A. fischerii	22	*A. fischerii*	6	*A. fischerii*	12
6	*P. luteum*	5	*P. luteum*	19	*P. luteum*	2
	A. fischerii	6	*A. fischerii*	12	*A. fischerii*	12
8	*P. luteum*	2	*P. luteum*	12	*P. luteum*	1
	A. fischerii	32	*A. fischerii*	23	*A. fischerii*	2
10	*P. luteum*	6	*P. luteum*	4	—	—
	A. fischerii	4	*T. viride*	10	—	—

bacteria, which were chiefly of one type, and must be deemed highly resistant to the action of this fumigant. Occasional colonies of *Rhizopus stolonifer* were present, as recorded in Table 2, but most of the common soil fungi occurring in Kettering loam, such as *Fusarium culmorum* and *F. caeruleum*, *Gliocladium roseum*, *Zygorrhynchus vuilleminii* and *Mucor spinosus*, were absent, even on plates made from soil treated with the smaller doses of carbon disulphide.

On the soil plates made 10 days after fumigation, however, the dominant micro-organisms after treatment with doses of carbon disulphide from 1 ml. upwards were no longer the resistant bacteria, but two ascosporic Ascomycetes, *Penicillium luteum* and *Aspergillus fischerii* (Table 3) which, like the bacterial species recorded from the first sampling, must be highly resistant to carbon disulphide. It is evident that this fumigant, at the higher dosages, must kill all but the most resistant fungi. Individuals of these resistant fungi may indeed be few in number in the normal soil before, and immediately after, treatment with carbon disulphide. But between the 24 hr. and the 10 day samplings, *Penicillium luteum* and *Aspergillus fischerii* must have multiplied rapidly, in the absence of effective competition from other fungal species, with the result that they developed almost in pure culture. In an earlier treatment of Kettering loam with carbon disulphide, *A. flavus* sometimes accompanied *A. fischerii* and *Penicillium luteum* on soil plates made from soil receiving high dosages of carbon disulphide. *Aspergillus flavus* is not an ascosporic form, but it produces sclerotia, which may well account for its resistance to carbon disulphide.

These observations on the dominance of *Penicillium luteum* and *Aspergillus fischerii* in soils treated with carbon disulphide show a remarkable parallel to the results obtained by Warcup (1951*a*) with a short-period steam treatment of soil especially designed for the isolation of slow-growing but heat-resistant Ascomycetes. Warcup obtained many such slow-growing Ascomycetes, rarely isolated from untreated soils, by the simple expedient of steaming the soil for a period of 3–5 min. The fungi surviving such treatment must have heat-resistant spores or other resting bodies, and ascosporic forms figured prominently in the lists recorded by Warcup, who attributed the rare occurrence of these fungi on plates made from untreated soil to their suppression by fast-growing species. From some sixty soil samples tested by the steam treatment from a wide range of localities throughout the British Isles, Warcup found *Aspergillus fischerii* to be the commonest Ascomycete (24 records). *Penicillium luteum* was the commonest species of *Penicillium* recorded after steam treatment (16 records).

Only one other point in connexion with this experiment requires further comment. *Trichoderma viride*, as noted above, was dominant only in the soil samples that had received the lowest dose of carbon disulphide tested (0·5 ml./250 g. moist soil). This observation does not, however, disagree with the ubiquity of *T. viride* in fumigated soil noted by Bliss (1951), because the field dose recommended by him was only 26·3 ml./ft.^{2} injected at 1 ft. depth (a concentration equivalent to rather less than 0·2 ml./250 g. soil).

Experiment 2. In this experiment, the tolerance to carbon disulphide of pure culture inocula of twelve isolates of fungi from Kettering loam was tested on an agar substrate, using a method modified from that employed by Jacks & Smith (1952). 15 ml. of 3 % malt agar were dispensed into the lids of sterilized 500 ml. specimen jars with ground glass stoppers; the cooled agar was inoculated centrally with mixed spore and mycelium inoculum taken from a mature slant culture on malt agar. After adding 0·5 ml. carbon disulphide to each jar, the lid with its agar film and fungus inoculum was fitted into the jar. Enough jars were inoculated with each fungus to permit testing periods of exposure to carbon disulphide ranging from 0·5 to 48 hr. at laboratory temperature; at the end of each predetermined exposure period, the culture-containing lid was removed from its jar, and covered with the lower half of a sterile Petri dish. All cultures were eventually incubated for a period at 25° C. sufficient to determine viability; as an additional precaution, parallel control cultures were set up in the lids of jars that received no carbon disulphide. It was found advisable to inoculate the agar medium immediately before the lid containing it was placed in position over its jar, as inocula that had commenced growth before exposure to the fumigant were often found to be less tolerant than those that had not; this occurrence was attributed to a presumed greater resistance to the fumigant of ungerminated spores than of germinated spores or growing mycelium. Maximum periods of exposure to carbon disulphide tolerated by the twelve different isolates of fungi are given in Table 4.

Table 4. *Tolerance of different soil fungi to carbon disulphide in agar culture*

Isolates		Maximum non-lethal period of exposure to carbon disulphide (hr.)
**Aspergillus fischerii*		>48
**Penicillium luteum*		>48
**Trichoderma viride*	T. 11	30
T. viride	T. 2	24
T. viride	T. 3	24
T. viride	T. 7	9
**T. viride*	T. 6	6
Penicillium citrinum		3
Rhizopus stolonifer		3
Zygorrhynchus vuilleminii		2
Fusarium culmorum		1
Gliocladium roseum		½

* Fungi originally isolated from carbon disulphide treated soil.

The results given in Table 4 agree well with those shown in Table 3 for the experiment on treatment of soil. *Aspergillus fischerii* and *Penicillium luteum* once more appear outstanding in their tolerance of this fumigant. The five isolates of *Trichoderma viride*, though differing quite widely in tolerance amongst themselves, were all markedly more tolerant of carbon disulphide than were the other species of common soil fungi tested.

MOVEMENT OF FORMALIN AND CARBON DISULPHIDE THROUGH MOIST SOIL

The two experiments to be described in this section illustrate the potential usefulness of the soil recolonization tube for this type of investigation. Time did not permit the carrying-out of further experiments necessary to establish properly the effect of soil moisture content and of other factors upon the movement of these fumigants through the soil.

Experiment 1. Six soil recolonization tubes were filled with soil at 22 % M.H.C.; in two tubes, the soil was left at this moisture content, in two it was brought to 38 % M.H.C. and in two to 44 % M.H.C. by adding water through the side-arms. The tubes were then allowed to stand overnight to permit distribution of the added water through the soil. Three ml. formalin were then added to the centre side-arm of each tube and the apparatus was sealed by rubber bungs for 24 hr. at laboratory temperature, after which the bungs were removed and replaced by 'Oxoid' metal caps. After a further 24 hr., samples of soil were taken from the seven side-arms of each tube for the preparation of soil plates, and fungal colonies were counted after 5 days' incubation. The counts of fungal colonies, which were chiefly of *Penicillium* species and of Mucoraceae, are given in Table 5. The colony counts for distances of 2, 4 and 6 in. from the point of injection represent means for four soil samples, i.e. from one side-arm on either side of the centre for each of the duplicate tubes.

Table 5. *Distribution of formalin in soil at different moisture contents, as shown by numbers of fungal colonies developing from soil samples taken at different distances from point of injection*

(Mean no. fungal colonies on soil plates.)

	Soil moisture content		
	22 % M.H.C.	38 % M.H.C.	44 % M.H.C.
At injection point	0	0	0
2 in. distant	8	0	0
4 in. distant	25	26	21
6 in. distant	22	27	10

It is obvious from the colony counts in Table 5 that, during 48 hr. elapsing since the original injection, the formalin has moved at least 2 in. but not as far as 4 in. from the point of injection. The sharp demarcation of the formalin effect upon the soil fungus flora agrees with the more extensive and prolonged observations of Warcup (1951*b*) in a field trial.

This sharply demarcated effect of formalin, which was confirmed in another experiment carried out at a moisture content of 50 % M.H.C., agrees with the suggestion that formalin moves through the soil chiefly in aqueous solution, rather than in the gas phase. Movement should therefore be facilitated by a high soil moisture content. In Table 5, only the figures for the 2 in. distance bear on this point, but it is suggestive that formalin failed to suppress soil fungi *only* at the lowest soil moisture content.

Experiment 2. As in the previous experiment, three pairs of soil recolonization tubes were set up with soil adjusted to moisture contents of 32, 45, and 67 % M.H.C., respectively. One ml. carbon disulphide was then added to each tube through the centre side-arm, after which the tubes were sealed for 24 hr. at laboratory temperature. After a further 24 hr. to permit dispersal of the fumigant, soil samples were taken from all side-arms for the making of soil plates. Mean numbers of fungal and bacterial colonies are given in Table 6.

Table 6. *Distribution of carbon disulphide at different moisture contents, as shown by numbers of fungal and bacterial colonies developing from soil samples taken at different distances from point of injection*

	Soil moisture content		
	32 % M.H.C.	45 % M.H.C.	67 % M.H.C.
No. fungal colonies at injection point	0	0	0
2 in. distant	0	1	2
4 in. distant	13	16	13
6 in. distant	24	24	21
No. bacterial colonies at injection point	17	25	24
2 in. distant	13	17	19
4 in. distant	15	8	7
6 in. distant	9	3	2

The number of fungal colonies show that in 48 hr. from the time of injection carbon disulphide has spread for at least 4 in. from the point of injection, as might have been expected from the volatile nature of this fumigant. Although it had been expected from the results of earlier workers, that carbon disulphide would spread more rapidly and for a greater distance in soil at the lowest moisture content, no such effect can be seen in Table 6, and further experiments are needed to elucidate this.

The numbers of bacterial colonies were highest on the soil plates made from samples taken at the actual point of injection, and decreased with increasing distance of samples from this point. This inverse relationship between numbers of bacterial and fungal colonies suggests that the bacterial colonies were able to develop only in the absence of serious competition from fungi, a reasonable supposition, in view of the fact that the acidified Czapek-Dox medium used was designed to favour development of fungi, but to suppress that of bacteria.

Recolonization of completely sterilized soil by fungi

For studies of soil recolonization, the soil recolonization tubes were set up as described under 'Methods' above. The tubes were packed with soil at a moisture content of 40 % M.H.C. before being sterilized by steaming for 1 hr. on 3 consecutive days. A quantity of unsterilized soil was then added to one end of the tube. In order to determine the sequence of fungi invading the steam-sterilized loam from an inoculum of the same soil unsterilized, a number of replicate tubes were set up at different times.

Although the actual sequence of fungal invasion has varied from time to time, and from one replicate tube to another, a fairly typical sequence was obtained from a single tube (see Fig. 3).

In this tube the order of fungal invasion was as follows: *Sordaria fimicola*, *Pythium acanthicum*, *Zygorrhynchus vuilleminii*, *Mucor spinosus*, *Trichoderma viride*, *Fusarium caeruleum*. It is also worth noting in Fig. 3 that *Sordaria fimicola* and *Pythium acanthicum* were not detected on soil plates made from later samplings of the earlier-colonized sampling sites, i.e. that these two fungi were eventually suppressed by later fungal colonizers following on behind.

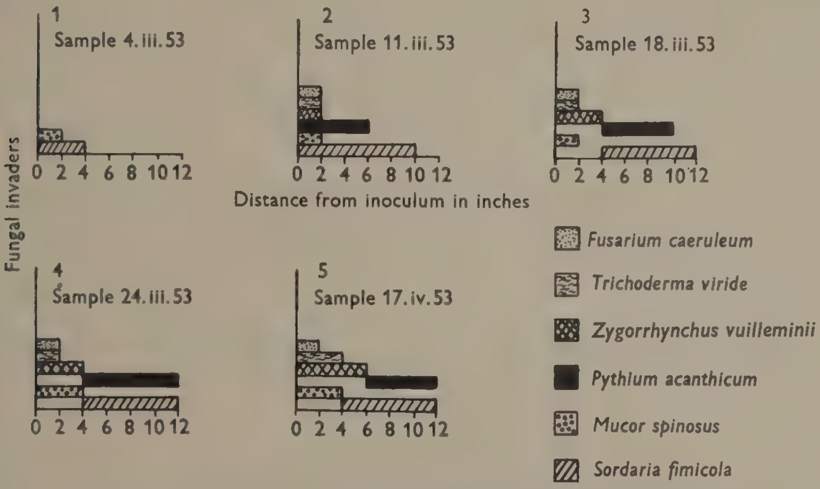

Fig. 3. A typical series of fungi re-invading steam-sterilized soil.

Although *Sordaria fimicola* was the leading fungal colonizer in this particular tube and in some others filled with similarly steam-sterilized and re-inoculated loam, in yet other tubes it failed to appear at all. Almost invariably, however, Phycomycetes were among the leading colonizers when the tubes were closely packed with soil at filling. If, on the other hand, the tubes were filled loosely, *Trichoderma viride* was almost always the leading fungal colonizer. This may explain why *T. viride* has sometimes been recorded as the dominant colonizer of steam-sterilized soil (Ludwig & Henry, 1943), but at other times has failed to gain an ascendancy (Warcup, 1951 *b*). It was further noted that few if any other fungi were able to follow *T. viride* after it had occupied the soil in the recolonization tube. Ludwig & Henry (1943) found that this fungus retained its dominance in a steamed soil for 80 days, the maximum period tested; Warcup (1951 *b*) recorded dominance of *T. viride* in a formalin-treated soil for 18 months. It is possible that those strains of *T. viride* producing either of the antibiotics gliotoxin or viridin are thereby enabled to occupy soil for a considerable period after colonization, to the virtual exclusion of most other fungi. Thus Evans & Gottlieb (1952) found that a particular isolate of *T. viride* produced gliotoxin, in biologically significant quantities, in sterilized soil without any organic amendment. Nevertheless, this is unlikely to be the sole explanation of the persistent dominance of *T. viride* in soil because only a minority of isolates of this fungus has been found to produce an antibiotic. None of twelve isolates of *T. viride* obtained at random from Kettering loam showed antibiotic activity against *Pythium deBaryanum.*

Apart from such particular effects as that of soil packing upon *Trichoderma viride*, which can probably be ascribed to the favourable effect of improved soil aeration, the sequence of fungal colonizers in sterilized Kettering loam was found to fall fairly closely in the order of their growth rates in pure culture, which were determined both on malt agar and through steam-sterilized soil.

Although the only variable so far shown to affect the sequence of fungal colonization of steam-sterilized soil has been the degree of soil packing, the method of study described above would obviously be suitable for a more extensive investigation.

Grateful acknowledgement is made to Dr S. D. Garrett of the Botany School, Cambridge, under whose supervision this work was carried out. Thanks are also due to the Agricultural Research Council for a studentship which made the work possible. The writer would also like to thank Dr E. W. Buxton, Dr N. F. Robertson and Dr H. C. Smith for their assistance with the taxonomy and Mr N. F. T. Elborn and Mr Clark for help with the photography and drawings, respectively.

REFERENCES

Bliss, D. E. (1951). The destruction of *Armillaria mellea* in citrus soils. *Phytopathology*, **41**, 665–683.

Brian, P. W. (1951). Antibiotics produced by fungi. *Bot. Rev.* **17**, 357–430.

Evans, E. (1954*a*). Soil recolonization tube for studying recolonization of sterilized soil by micro-organisms. *Nature, Lond.*, **173**, 1196.

Evans, E. (1954*b*). The effect of soil sterilizing agents on fungal ecology. Ph.D. Thesis, University of Cambridge.

Evans, E. & Gottlieb, D. (1952). The role of gliotoxin in soil. *Phytopathology*, **42**, 465–466.

Jacks, H. & Smith, H. C. (1952). Soil disinfection. XII. Effect of fumigants on growth of soil fungi in culture. *N.Z. J. Sci. Tech.* A, **33**, 69–73.

Ludwig, R. A. & Henry, A. W. (1943). Studies on the microbiology of recontaminated sterilized soil in relation to its infestation with *Ophiobolus graminis* Sacc. *Canad. J. Res.* **21**, 343–350.

Warcup, J. H. (1950). The soil-plate method for isolation of fungi from soil. *Nature, Lond.*, **166**, 117.

Warcup, J. H. (1951*a*). Soil-steaming: a selective method for the isolation of ascomycetes from soil. *Trans. Brit. mycol. Soc.* **34**, 515–518.

Warcup, J. H. (1951*b*). Effect of partial sterilization by steam or formalin on the fungus flora of an old forest nursery soil. *Trans. Brit. mycol. Soc.* **34**, 519–532.

Warcup, J. H. (1952). Effect of partial sterilization by steam or formalin on damping-off of sitka spruce. *Trans. Brit. mycol. Soc.* **35**, 248–262.

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Trans. Brit. mycol. Soc. **38** (4), 347–365 (1955).

GRAMINICOLOUS PYRENOMYCETES. V. CONIDIAL STATES OF *LEPTOSPHAERIA MICHOTII*, *L. MICROSCOPICA*, *PLEOSPORA VAGANS* AND THE PERFECT STATE OF *DINEMASPORIUM GRAMINUM**

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(With 5 Text-figures)

By means of cultures the connexions between the following Pyrenomycetes and Fungi Imperfecti have been demonstrated: *Leptosphaeria michotii* and *Coniothyrium scirpi*, *Leptosphaeria microscopica* and *Phaeoseptoria festucae*, *Pleospora vagans* and a species of *Hendersonia*. The perfect state of *Dinemasporium graminum* is described as *Phomatospora dinemasporium* sp.nov. The synonymy of some of these fungi is discussed.

The task of connecting Fungi Imperfecti with their perfect states is important, but fraught with many difficulties. Where type material of the conidial form has been preserved, there is the difficulty of comparing it with cultures, which may show greater variability than collections on the host plant. Where type or authentic material is no longer preserved the task becomes hazardous, since comparison is then made between often inadequate descriptions and cultures. It has also been shown that unrelated fungi may have conidial states which are distinguishable only with difficulty (see, for example, Simmons, 1952). In comparatively few cases can one be satisfied in reducing a name in the Fungi Imperfecti to synonymy. In the remaining cases it seems wiser merely to describe the conidial form obtained in culture, to compare it where possible with material collected on the host, and to do no more than suggest the names in the Fungi Imperfecti which might be considered as synonyms.

Cultures have been prepared from collections of perithecia and conidia of fungi on grasses, and the present paper describes the results of these isolations. The cultures were prepared by crushing a single perithecium or pycnidium in a drop of sterile water on a slide, transferring part of the spore suspension to agar plates with a fine pipette. The remaining spore suspension was mounted in cotton blue in lactic acid, and the slide preserved. The measurements in the following tables are taken from these 'isolation slides' and thus do not represent the whole range of variation of spore size in the collections. Cultures were prepared from single spores or asci, or occasionally from groups of spores, and when the hyphae from germinating spores had grown free from bacteria, transfers were made to oat agar slopes (6 × 1 in. boiling tubes containing about 20 ml. of medium). The cultures were incubated at room temperature in diffuse light or in direct light from a window, and in most cases examined within 2 months.

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* Part of a thesis submitted for the degree of Ph.D. in the University of London.

(1) **Leptosphaeria michotii** (Westend.) Sacc. (Fig. 1)

The description below is drawn up from material on *Dactylis glomerata* (Mycological Herbarium of the University of Sheffield, no. 1020). *Perithecia* small, globose, black or dark brown, with a small papillate ostiole, arising from a submerged mycelium, hyaline to pale brown in colour, septate, 2–3 μ wide, penetrating both lignified and parenchymatous tissues; the perithecia measure 130–250 μ in diameter and occur on the inflorescence axis, the internode, nodes and leaf sheaths, of the current or previous year. The perithecial wall is 20–30 μ thick and is made up of dark brown polygonal, thin-walled cells, about 10–20 μ across. *Asci* numerous cylindrical or club-shaped, sessile, rounded at the apex, possessing a double wall, 8-spored, 62–100 × 12–14 μ; 'paraphyses' about as long as the asci, septate, cylindrical 2–4 μ in width. *Ascospores* biseriate, or more closely packed within the ascus, cylindrical, 2–3 septate, slightly constricted at the septa, end cells rounded, brown in colour, becoming darker with age 14–22 × 4–5 μ. On germination a single germ-tube is usually produced from one of the end cells, occasionally from both, rarely from the central cell.

Conidial stage. Cultures were prepared from single ascospores. Transfers were made to oat agar and potato-dextrose agar. On these media the fungus grew fairly rapidly, forming a submerged brown mycelium and a small amount of white aerial mycelium. When observed 6 weeks later perithecia and pycnidia were found in cultures on both media (Fig. 1 C). The pycnidia were globose, brown, thin-walled bodies (wall 15–20 μ thick) with a small papillate ostiole, occurring either singly or grouped together, and measuring 110–250 μ in diameter. They contained numerous dark brown oval spores (Fig. 1 E), measuring 6–10 × 3–5 μ (usually 7–9 × 4–4·5 μ).

The pycnidia belong to the form genus *Coniothyrium* and match the description of *C. scirpi* Trail (1889). Pycnidia have also been found on *Dactylis*, having the same distribution as the perithecial stage and also occurring occasionally on the glumes. A few collections have been made of the perithecial and pycnidial stages occurring together (Fig. 1 A). On *Dactylis* the pycnidia are small, dark brown, globose, with a small projecting papilla, measure 90–170 μ in diameter, and contain dark brown oval spores measuring 5–10·5 × 4–5 μ (usually 7–10 × 4–4·5 μ).

The type of *Leptosphaeria michotii* (Herb. Hort. Bot. Bruxellensis no. 1218) has been examined by kind permission of Prof. W. B. Robyns of the Brussels Botanic Garden. It consists of a single stem fragment of *Juncus squarrosus*. Beneath the epidermis numerous perithecia were present. A few of these were mounted, but none contained ripe asci of *L. michotii*. However, occasional ascospores were found (Fig. 1 D). They are brown, 2-septate, the central cell slightly swollen, the end cells rounded; they measure 17–21 × 4–6 μ. Since these ascospores match sufficiently closely the original description no further search was made, in order to conserve

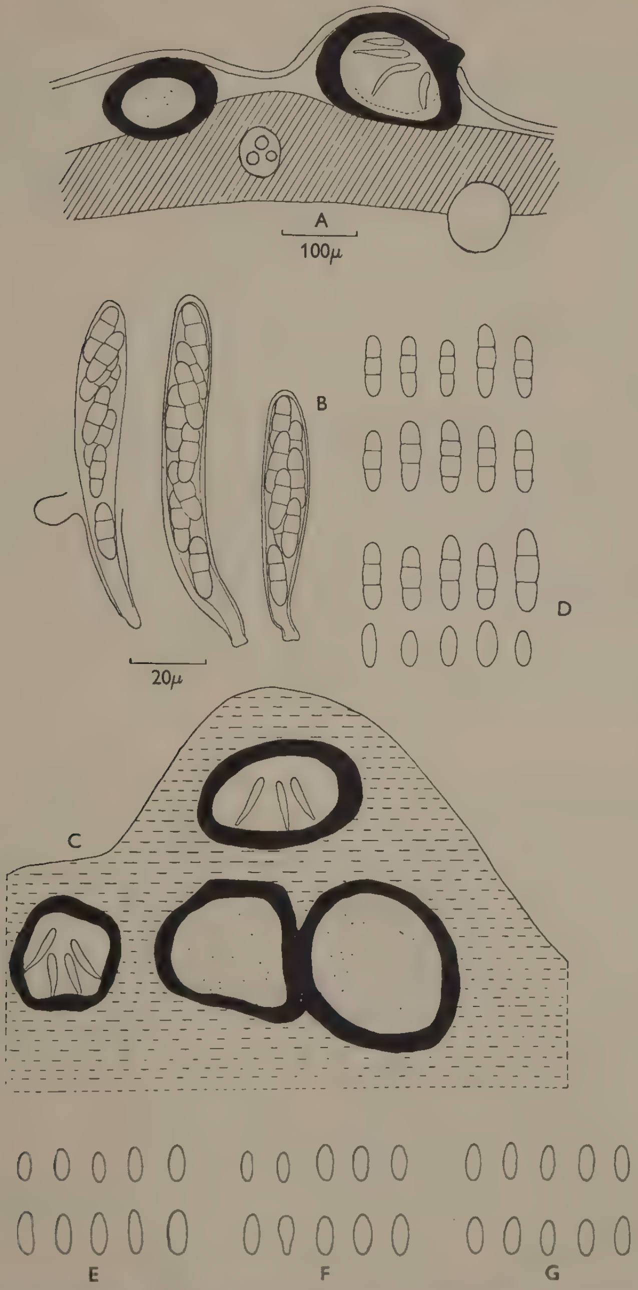

Fig. 1. *Leptosphaeria michotii.* A, T.S. stem with a perithecium and a pycnidium (stippled); B, asci and ascospores; C, section of oat agar culture derived from a single ascospore showing perithecia and pycnidia; D, ascospores and conidia from the type specimen of *L. michotii*; E, pycnospores from culture; F, pycnospores from *Dactylis*; G, pycnospores from type specimen of *Coniothyrium scirpi.* A and C to same scale; B, D, E, F and G to same scale.

the type specimen. The specimen also contained pycnospores which matched those described above, but showing a slightly greater range of size, measuring 7–13·5 × 3·5–5·5 μ.

I have also examined a slide, probably prepared from the type specimen of *Coniothyrium scirpi* Trail, preserved in the University of Aberdeen. According to Prof. Matthews (*in litt.*) there is no other material of *Coniothyrium* on *Eleocharis palustris* in the Trail Herbarium. The slide is labelled '*Coniothyrium scirpi* sp.n. from Scirpus palustris. Loch Acray, Perthshire. 15/9/88, Cly.' It appears to be a lactophenol mount of a crushed pycnidium, ringed with Canada balsam but now somewhat dried out. Few details of the structure of the pycnidium could be elucidated, but numerous spores were present; they were pale yellow to brown in colour, smooth, elliptical in shape, and measuring 9–11 × 3·5–4·5 μ (mostly 9–10 × 4 μ)—see Fig. 1 G.

I regard the material and cultures from *Dactylis* as matching type material of both *Leptosphaeria michotii* and *Coniothyrium scirpi*.

Perithecia have been previously recorded from a wide range of monocotyledonous hosts (see, for example, Oudemans, 1919), and I have made collections on *Agropyron repens*, *Deschampsia caespitosa*, *Festuca rubra*, *Nardus stricta* and *Typha latifolia*, in addition to the numerous collections on *Dactylis*. Pycnidia have been found on the following hosts: *Agropyron repens*, *Brachypodium pinnatum*, *Calamagrostis epigeios*, *Deschampsia caespitosa*, *Holcus lanatus*, *Melica uniflora*, *Nardus stricta* and *Phalaris arundinacea*. Cultures made from single pycnospores from several of these collections matched those derived from ascospores.

(2) **Leptosphaeria microscopica** Karst. (Fig. 2)

L. microscopica was described by Karsten (1872) from leaves of various grasses. *L. culmorum* Auersw. is generally accepted as a synonym, but since this name was published without a description various authors (e.g. Saccardo, 1883; Bisby & Mason, 1940) regard *L. culmorum* as a nomen nudum, and take *L. microscopica* as the valid name. Others (e.g. Winter, 1887; Muller, 1950) have accepted the name *L. culmorum*. Unfortunately, Karsten's specimens are not available (H. Roivainen, *in litt.*).

The fungus is widely distributed on numerous Monocotyledons, especially grasses (see Oudemans, 1919). I have collected perithecia on the following hosts: *Agropyron junceum*, *A. repens*, *Ammophila arenaria*, cultivated barley, *Calamagrostis epigeios*, *C. lanceolata*, *Cynosurus cristatus*, *Dactylis glomerata*, *Deschampsia caespitosa*, *Elymus arenarius*, *Festuca arundinacea*, *F. pratensis*, *Holcus lanatus*, *H. mollis*, *Lolium perenne*, *Melica uniflora*, *Nardus stricta*, *Phalaris arundinacea*, *Phragmites communis* and cultivated wheat. The following description is based on material from *Dactylis glomerata*.

Mycelium immersed in the tissues of the internodes, nodes, leaf sheaths, and inflorescence axis, confined mainly to parenchymatous tissues but occasionally penetrating lignified tissue, branched, septate, pale yellow to brown in colour, 2–4 μ wide. *Perithecia* occur in rows between the vascular bundles, raising the epidermis and penetrating it by a short, blunt, black neck; they are black globose, often elongated along the long axis of the

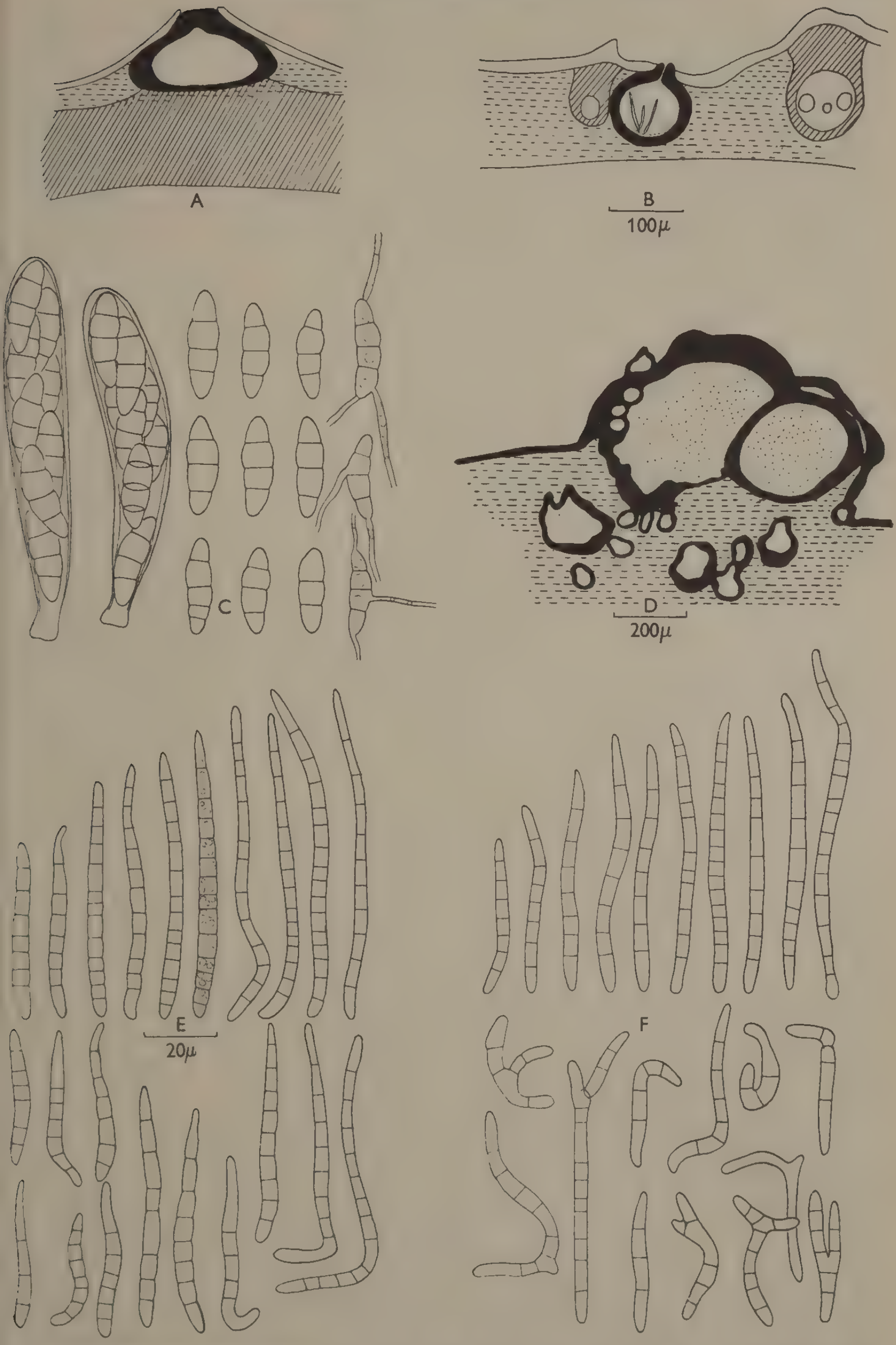

Fig. 2. *Leptosphaeria microscopica.* A, T.S. stem and perithecium; B, T.S. leaf sheath and pycnidium; C, asci and ascospores; D, section of oat agar culture derived from a single ascospore showing pycnidia (stippled) and perithecia; E, pycnospores from *Dactylis*; F, pycnospores from culture.

stem, and flattened below when growing on the stem. The wall is uneven in thickness (see Fig. 2 A) 15–20 μ thick above, 10–15 μ thick at the sides, sometimes almost absent below, and is composed of irregular brown polygonal cells 18–24 μ wide. *Asci* are numerous, broadly clubshaped, sessile, with double membranes, 8-spored and 68–104 × 15–18 μ; they are interspersed by septate branched 'paraphyses' 2–4 μ in width. *Ascospores* are biseriate in the upper part of the ascus and uniseriate below, pale yellow to golden in colour, most frequently 3-septate (but occasionally 4-septate) broadly fusoid, inequilateral, constricted at the septa but especially at the median septum, the second cell often more swollen than the rest, and 22–28 × 7–8·5 μ. On germination a germ tube is usually put out from one or both end cells, and also occasionally from a central cell (Fig. 1 C).

Conidial stage. Cultures were prepared on various media from asci and ascospores. On oat agar fruit-bodies were observed after 3 months. At the surface of the medium black stromatic masses up to 2 mm. in diameter were formed. When these were sectioned they were found to be composite structures containing large pycnidia, and smaller perithecia (Fig. 2 D). Perithecia were found in cultures derived from a single ascospore. The perithecia varied in diameter from 200 to 400 μ and contained asci and ascospores closely resembling those described above. The pycnidia, which were up to 600 μ in diameter, had dark walls up to 60 μ thick. The contents of the pycnidia consisted of large numbers of brown elongate pycnospores produced from sporogenous cells lining the wall of the pycnidium. The pycnospores showed great variety in shape and size (see Fig. 2 F), but the more typical spores were cylindrical or tapering towards the upper end, more or less curved, with 3–15 septa, slightly constricted at the septa, and 30–96 × 4–5·5 μ.

Pycnidia resembling those described were also found on *Dactylis*. The pycnidia on the host occur most frequently on the upper leaf-sheaths and internodes during August and September. They are visible as small black dots beneath the epidermis, between the vascular bundles (Fig. 1 B). They are globose, brown in colour, with a wall 10–15 μ thick, composed of brown polygonal cells up to 18 μ in width, but the wall is thicker and darker near the ostiole; ten pycnidia measured 120–190 μ in diameter. The pycnospores are produced from the inner wall cells on the lower half of the pycnidium; they are rather more regular than those produced in culture; yellow to brown in colour, cylindrical or tapering, 3–15 septate, frequently constricted at the septa, and each cell often contains several small guttules; they measure 44–95 × 4–5·5 μ (Fig. 2 E).

Cultures have also been prepared from the collections of perithecia or conidia from various hosts. Table 1 shows the results of these isolations, and measurement of conidia, and ascospores on the host and in culture.

Table 1 shows that there is some variation both in the size of ascospores and conidia. In the material listed ascospores vary in size from 22–28 × 6–8·5 μ on grasses and 19–32 × 5–8 μ in cultures on oat agar. A proportion of four (or rarely five) septate spores occurs in most collections and cultures. The conidia vary in size from 36–82 × 4–6 (usually 4–4·5) μ on the host, and appear to have a basic number of seven septa, although additional septa may be laid down in certain cells so that spores with up to eleven septa are occasionally found. In culture the conidia range in size from 30–96 × 3·5–6 (usually 4–4·5) μ and contain 3–15 septa, although spores with fewer than seven septa are probably immature. It is interesting to note the behaviour of different cultures. Starting from ascospores or conidia it is possible to obtain both perithecia and pycnidia in culture. However, cultures started from ascospores seem to produce perithecia more readily than pycnidia, whilst the converse is true for cultures started from conidia.

Table 1. *Dimensions of ascospores and conidia of* Leptosphaeria microscopica *on various hosts and in 2-month-old cultures on oat agar*

Herb. no.	Host	Type of fruit-body produced in culture	Dimensions on host (μ)		Dimensions in culture (μ)	
			Ascospores	Conidia	Ascospores	Conidia
rithecia						
188	*Ammophila arenaria*	per. & pyc.	24–28 × 6–7	—	20–26 × 5–6	50–60 × 3·5–4
195	*Cynosurus cristatus*	per.	23–26 × 6–8	—	24–27 × 6–7	—
353	*Nardus stricta*	per.	24–28 × 6–8	—	—	—
366	*Phalaris arundinacea*	per. & pyc.	23–24 × 6–7	—	24–32 × 6–8	40–60 × 3·5–5
368	*P. arundinacea*	per.	24–27 × 7–8	—	24–26 × 6–7	—
373*a*	*Festuca arundinacea*	per.	22–26 × 6·5–8	—	22–25 × 6–7	—
378	*F. pratensis*	per.	24–28 × 7·5–8·5	—	—	—
352	*Holcus lanatus*	per.	24–28 × 6·5–8	—	19–26 × 6–8	—
354*a*	*Deschampsia caespitosa*	per.	24–26 × 6–8	—	21–26 × 6–7	—
604	*Agropyron repens*	per. & pyc.	—	—	24–26 × 7–8	—
093	*Dactylis glomerata*	per. & pyc.	22–28 × 7–8·5	—	22–26 × 7–8	30–96 × 4–5·5
onidia						
196	*Cynosurus cristatus*	pyc.	—	44–60 × 4–4·5	—	32–68 × 3·5–4
200	*Deschampsia caespitosa*	per. & pyc.	—	40–72 × 4–4·5	24–26 × 6–7	46–60 × 3·5–4
205	*Alopecurus pratensis*	pyc.	—	40–60 × 4–4–5	—	46–80 × 4–6
207	*Poa pratensis*	pyc.	—	36–56 × 4–5	—	40–90 × 4–5
124	*Lolium perenne*	pyc.	—	46–76 × 4–4·5	—	54–88 × 4–4·5
373*b*	*Festuca arundinacea*	pyc.	—	40–82 × 4·5–6	—	42–74 × 4–5
350	*Holcus lanatus*	pyc.	—	48–72 × 4–4·5	—	48–74 × 3·5–4
478*b*	*Phragmites communis*	per.	—	42–58 × 3·5–4	24–28 × 6–8	—

The conidia are referable to the form-genus *Phaeoseptoria* Speg. Dr R. Sprague has determined material of *Leptosphaeria microscopica* conidia sent to him (Herb. Sheffield 1093) as *Phaeoseptoria festucae* Sprague described (Sprague, 1943*b*) from 'languishing leaves of *Festuca rubra*', with 8–11 septate pycnospores, measuring 50–85 × 2·8–4·8 μ. Various other species of *Phaeoseptoria* have been distinguished by Sprague, and it is possible that some of these may represent conidia of *Leptosphaeria microscopica* on different hosts. In particular *Phaeoseptoria airae* (Grove) Sprague from *Deschampsia caespitosa* with spores 9–10 septate, 51–56 × 3·0–3·5 μ (later (Sprague, 1950) given as 60–75 × 2·5–3 μ), falls within the range listed in Table 1, and it may be noted that cultures of conidia from *Deschampsia caespitosa* yielded perithecia of *Leptosphaeria microscopica*.

Both perithecia and pycnidia of *L. microscopica* are found most commonly on the upper leaf sheaths of grasses in late summer as the leaves become moribund. On *Dactylis* perithecia persist throughout the winter, but pycnidia are difficult to find after October (see Webster, 1956).

There is a striking similarity between pycnospores obtained from cultures of *Leptosphaeria microscopica* and those described by Hughes (1949) from cultures of *L. nigrans*. This was confirmed by comparison of single-ascospore cultures of *L. nigrans* from *Dactylis glomerata* isolated on 30 May 1952. Transfers were made to oat agar, potato-dextrose agar and to steam-sterilized *Dactylis* stems. After 2 months pycnidia were formed, but only on the first of these media. Hughes reported the production of pycnidia in cultures of *Leptosphaeria nigrans* from wheat on potato-dextrose agar and on steamed wheat leaves. The pycnidia formed in the present investigations resemble those described by Hughes.

The fungus on oat agar forms at the surface of the medium a close felt of grey aerial mycelium; in the medium intense black colour is produced due to the dark pigmentation of the submerged hyphae, which are branched and septate, 2–3 μ wide. The pycnidia are formed at the surface and are black, globose with a small flattened papilla-like neck, and measured 80–170 μ. The walls of the pycnidium are about 20 μ thick, and made up of dark polygonal cells 5–8 μ wide. Pycnospores are produced from cells on the inner wall of the pycnidium. The pycnospores are dark brown in mass, pale brown or yellow when viewed singly, variable in length, measuring 32–88 × 3·5–5 μ, with 3–14 transverse septa, not constricted, wider at the base, tapering to the apex, straight or curved, ends rounded. Hughes gives measurements of pycnospores as 49·5–97·2 × 3–5 μ from agar cultures, with 7–16 transverse septa. 'Pycnospores with less than seven transverse septa were probably immature.'

Hughes has compared the pycnidia obtained in cultures with *Septoria alopecuri* var. *calamagrostidis*. Pycnospores from the type specimen are figured in Fig. 3 D. The similarity with well-developed pycnospores of *Leptosphaeria nigrans* is most striking. The dimensions of pycnidia and pycnospores of these two species of *Leptosphaeria* in culture on oat agar are compared below.

Table 2

	Diameter of pycnidia (μ)	Pycnospores	
		Size (μ)	Septa
L. microscopica	Up to 600	30–96 × 4–5·5	3–15
L. nigrans	80–170	32–88 × 3·5–5	3–14

In spite of the resemblance, the size of the pycnidia and the difference in conidial width, together with perithecial formation in *L. microscopica* and other cultural characters form a satisfactory basis for separating these two forms in culture. However, the similarity of the conidia of these two species indicates the difficulties in linking together names for conidial and ascigerous states in these fungi.

Grove (1937, p. 77) stated that *Hendersonia culmicola* var. *minor* Sacc. 'is no doubt the pycnidial stage of *Leptosphaeria microscopica*, which continually occurs with it'. This statement is not supported by cultural evidence. Various isolates of *Hendersonia culmicola* var. *minor* have been made, but bear no comparison to those of *Leptosphaeria microscopica*.

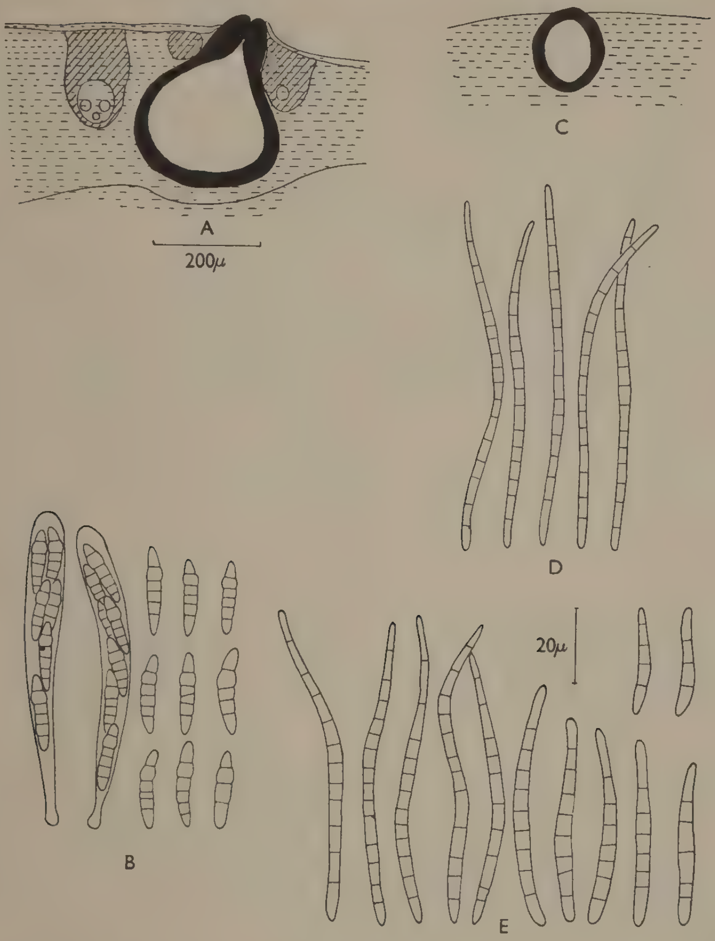

Fig. 3. *Leptosphaeria nigrans.* A, T.S. leaf sheath and perithecium; B, asci and ascospores; C, section of culture showing a pycnidium; D, pycnospores from the type specimen of *Septoria alopecuri* var. *calamagrostidis*; E, pycnospores from culture.

(3) **Pleospora vagans** Niessl. (Fig. 4)

This fungus was described by Niessl (1876), who distinguished three forms: (*a*) arenaria, (*b*) pusilla and (*c*) Airae. Berlese (1900) added *P. vagans* var. *sparganii* based on *Pleospora sparganii* Cooke. Perithecia of *P. vagans* have since been collected on numerous grasses and other Monocotyledons (see Oudemans, 1919; Wehmeyer, 1949). I have collected perithecia on the following hosts: *Agropyron repens*, *Agrostis* sp., *Alopecurus pratensis*, *Ammophila arenaria*, *Anthoxanthum odoratum*, *Arrhenatherum elatius*, *Brachypodium sylvaticum*, *Bromus ramosus*, *Calamagrostis epigeios*, *C. lanceolata*, *Dactylis glomerata*, *Deschampsia caespitosa*, *Elymus arenarius*, *Festuca arundinacea*, *F. pratensis*, *F. rubra*, *Holcus mollis*, *Hordeum murinum*, *Lolium perenne*,

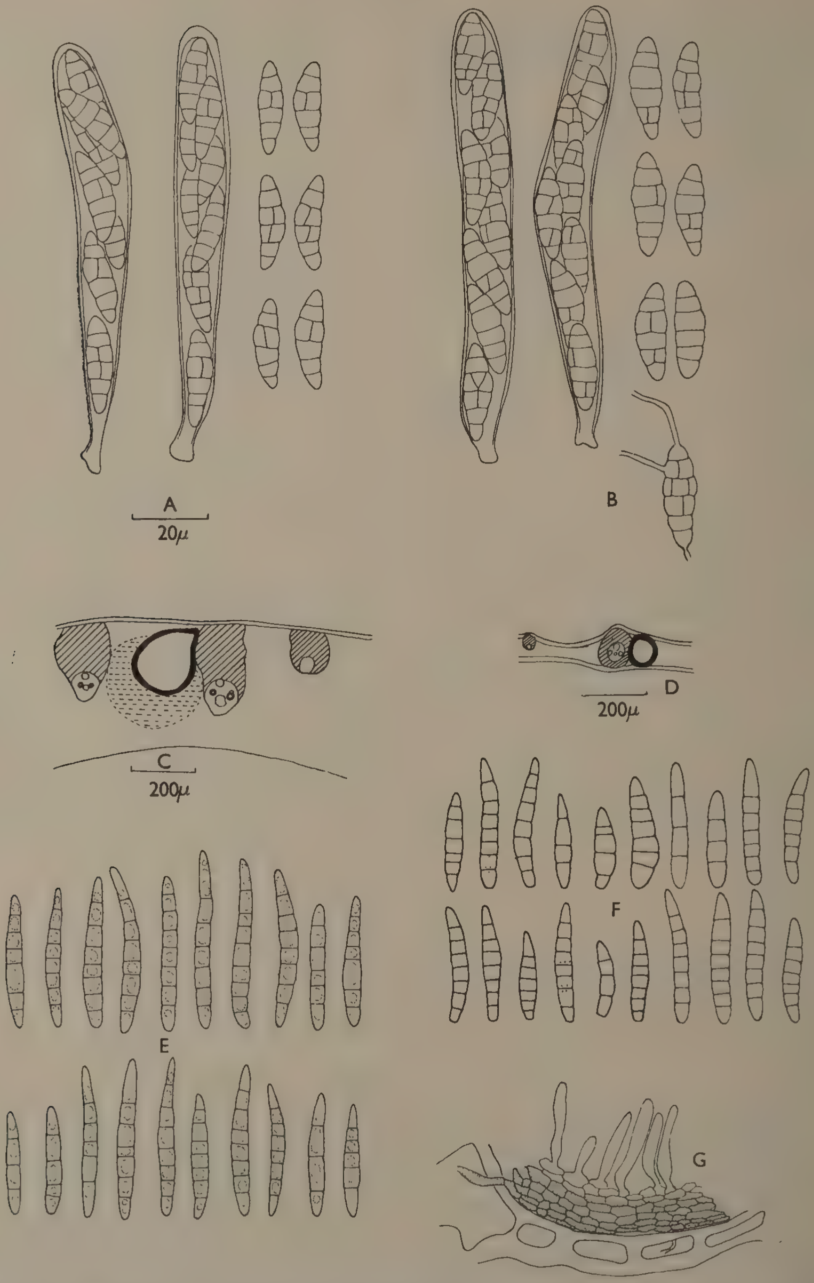

Fig. 4. *Pleospora vagans.* A, asci and ascospores formed in culture on oat agar derived from a single pycnospore; B, asci and ascospores from *Dactylis*; C, T.S. leaf sheath of *Dactylis* with a perithecium; D, T.S. leaf sheath and pycnidium; E, pycnospores formed in culture on sterilized grass stems derived from a single ascospore; F, pycnospores from *Dactylis*; G, a portion of the pycnidial wall in section showing developing pycnospores.

Phalaris arundinacea, *Phragmites communis* and *Typha latifolia*. The specimen described below was collected on *Dactylis glomerata*. It does not match exactly any of Niessl's varieties, but as Wehmeyer (1949) has shown, intergrading forms between the varieties exist.

Mycelium immersed in the parenchymatous tissues of the leaf-sheath, stem and nodes, hyaline to pale brown in colour, branched, septate hyaline, 3–4 μ wide. *Perithecia* produced between the vascular bundles (see Fig. 4 C) and are thus often arranged in rows: raising the epidermis slightly, with the small inconspicuous conical necks projecting; the perithecial wall is brown, about 15–20 μ thick, composed of brown-walled flattened polygonal cells, 8–22 μ wide, and bearing numerous hyphae at the base. Mature perithecia measure 180–220 μ in diameter. *Asci* numerous arising at the base of the perithecium, expanding between the cylindrical septate 'paraphyses' which are 2–4 μ in width; mature asci club-shaped or cylindrical, shortly stalked, rounded at the apex, with two membranes, 8-spored and measure 92–124 × 14–16 μ. *Ascospores* yellowish brown, biseriate in the upper portion of the ascus, uniseriate below, broadly fusoid, inequilateral, divided by five (or occasionally six) transverse septa, and slightly constricted at the septa. The third cell from the apex is rather wider than the rest, the end cells are rounded; one or more of the four central cells are divided by longitudinal septa, but occasionally spores without longitudinal septa may be found; the ascospores measure 22–28 × 7·5–9·5 μ.

The ascospores germinate within a few hours in water producing germ-tubes apparently from any cell. Cultures were prepared from single ascospores on several occasions.

Stems of *Dactylis* sterilized by exposure to propylene oxide vapour and incubated at room temperature in boiling tubes containing sterilized damp sand, and *Sphagnum* were inoculated with single ascospore cultures on 13 November 1950. When examined on 24 January 1951 a few brown pycnidia had formed on the surface mycelium covering some of the stems; the pycnidia contained brown, elongate, 7-septate pycnospores. The conidial stage belongs to the form-genus *Hendersonia*. A similar pycnidial form is found associated with *Pleospora vagans*, on *Dactylis*. In order to confirm the observation that this *Hendersonia* is the conidial stage of *Pleospora vagans*, cultures were made from single ascospores and single pycnospores from material on *Dactylis* on various media and on sterilized grass stems on 15 December 1951, incubated in diffuse light at room temperature and examined on 9 February 1952. The cultures of *Pleospora vagans* and *Hendersonia* on oat agar were identical in growth and appearance, and in both cultures ripe perithecia of *Pleospora vagans* were found. Perithecia were also found in cultures of both isolates on sterilized grass stems. We may therefore conclude that *P. vagans* is homothallic and that its conidial state is a *Hendersonia*.

The pycnidia of *Pleospora vagans* on the host have a similar distribution to the perithecia, occurring between the veins most frequently on the upper internodes and nodes; they are however smaller, measuring 95–110 μ in diameter, globose or somewhat flattened with a small papillate ostiole; the wall is brown, 12–15 μ thick, and composed of polygonal cells. The inner layers of the wall are hyaline and bear the pycnospores; individual cells appear to elongate to form the cylindrical body of the spore (Fig. 4 G), which becomes divided by transverse septa. Mature pycnospores are pale yellow in colour, 3–7 septate, faintly constricted at the septa, straight or slightly curved, tapering above, rather abruptly truncate below; each cell contains several small guttules which are grouped together near the septa (Fig. 4 F): the pycnospores measure 24–46 × 4–6 μ. They germinate by producing germ tubes, apparently from any cell.

The cultures on oat agar slopes are grey to black in colour with a limited aerial mycelium with white or pale rose tints; at the upper end of the tube the mycelium in the substratum is orange to brown in colour with small black stromatic masses. Perithecia only were observed in these cultures, for the most part embedded in the medium. These resembled those formed on the host; the asci measured 112–122 × 14–16 μ; the ascospores were slightly narrower than those on the host, measuring 23–28 × 7–8 μ. The pycnidia formed in culture on the sterilized grass stems were superficial, dark brown, depressed globose, rather larger than those on the host 100–150 μ in diameter; the pycnospores were yellow to brown in colour 3–7 septate, usually with a single large guttule in each cell; they measured 27–48 × 4–5 μ.

Cultures have also been prepared from conidia and ascospores from various hosts, and the dimensions of these collections and the behaviour of the cultures are tabulated in Table 3. The conidia obtained in some of these cultures show greater variation than those described in cultures from *Dactylis*. For example, conidia varying in size from 34–60 × 4·5–6 μ containing 3–14 septa were found in cultures started with ascospores from *Anthoxanthum odoratum* (1192*b*), and conidia varying from 36–64 × 4–6 μ with 7–10 septa have been found in cultures started with conidia from *Melica uniflora* (1361). The conidia on the host generally show less variation in size; conidia usually measure 26–40 × 3·5–5 μ. I have collected conidia on the following hosts: *Anthoxanthum odoratum*, *Calamagrostis epigeios*, *Cynosurus cristatus*, *Dactylis glomerata*, *Deschampsia caespitosa*, *Elymus arenarius*, *Festuca arundinacea*, *F. rubra*, *Helictotrichon pubescens*, *Holcus lanatus*, *Hordeum murinum*, *Melica uniflora*, *Phalaris arundinacea*, *Phragmitis communis* and cultivated barley.

Some of the collections of perithecia listed in Table 3 probably correspond with Niessl's varieties: e.g. var. *arenaria* described on *Elymus arenarius* is probably represented by collections 1210*a* and 1393, whilst var. *Airae* described from *Deschampsia caespitosa* is probably represented by collection 1607.

Hendersonia crastophila Sacc. is a name which should be considered as a possible synonym of *Pleospora vagans*. Saccardo's (1879) description of this fungus from *Phragmites communis* gives 'stylosporis bacillari-fusoideis, utrinque rotundatis, 35 × 5·5, 7–8 septatis, eguttulatis, fuligineis'. Unfortunately, there is no type material available for study. Sprague (1943*a*, *b*) discussed this species, and later (1950) gave a more extensive account with a list of grass hosts, citing *Wojnowicia graminis* (McAlp.) Sacc. et Sacc. as a synonym. However, in more than 150 isolations of *W. graminis* from wheat and grasses Sprague (1935) did not report perithecia, which were readily obtained in 2-month-old oat agar culture started from pycnospores in the present study. I have studied material and cultures of *W. graminis* from *Agropyron pungens* and wheat stubble, but this fungus is different from *Pleospora vagans*. In the absence of type material of *Hendersonia crastophila*, it is difficult to know whether Sprague is correct in regarding *H. crastophila* and *Wojnowicia graminis* as synonyms. However, *W. graminis* is not related to *Pleospora vagans*.

Table 3. *Dimensions of ascospores and conidia of* Pleospora vagans *on various hosts and in 2-month-old cultures on oat agar*

Herb. no.	Host	Type of fruit-body produced in culture	Dimensions on host (μ)		Dimensions in culture (μ)	
			Ascospores	Conidia	Ascospores	Conidia
1187	*Ammophila arenaria*	per.	22–30 × 7–10	—	24–28 × 6–8·5	—
1192*b*	*Anthoxanthum odoratum*	per. & con.	23–28 × 7–9	—	24–28 × 6·5–8	34–60 × 4·5–6
1210*a*	*Elymus arenarius*	per. & con.	22–28 × 7–9	—	20–28 × 7–10	40–56 × 4·5–5
1383	*Agropyron repens*	per.	22–28 × 7–10	—	22–26 × 7–9	—
1393	*Elymus arenarius*	per. & con.	24–30 × 8·5–11	—	25–30 × 8–10	30–32 × 4–4·5
1478*a*	*Phragmites communis*	per. & con.	22–30 × 7–10	—	22–28 × 7–9	33–50 × 3·5–4·5
1607	*Deschampsia caespitosa*	per.	24–28 × 7·5–8·5	—	24–27 × 7–8	—
1627	*Typha latifolia*	per.	22–27 × 7–8·5	—	22–28 × 6·5–8	—
1190	*Phragmites communis*	con.	—	36–44 × 3·5–4	—	32–38 × 4–4·5
1192	*Anthoxanthum odoratum*	con.	—	26–38 × 4–5	—	30–56 × 4–5
1199	*Helictotrichon pubescens*	per.	—	28–42 × 3·5–4·5	20–24 × 7·5–10	—
1352*a*	*Holcus lanatus*	per.	—	26–38 × 4–4·5	24–28 × 8–10	—
1361	*Melica uniflora*	per. & con.	—	27–37 × 4·5–6	24–28 × 7–8	36–64 × 4–6
1209*b*	*Arrhenatherum elatius*	per.	—	26–36 × 4–5	22–26 × 7–8	—
1477	*Phragmites communis*	con.	—	31–64 × 4–6	—	28–52 × 4–6
1606	*Deschampsia caespitosa*	per.	—	32–49 × 4·5–6	23–29 × 7–8·5	—

Wehmeyer (1949) cites *P. fuegiana* Speg. and *P. forsteri* as synonyms of *P. vagans*. During examination of specimens in Herb. Kew it became evident that *Sphaeria clara* Auersw. ex Cooke is also a synonym. The name dates from the publication by Cooke (*Grevillea*, 1877, 5, 121) of '*Sphaeria clara* Awd. Perithecia scattered, seated beneath the cuticle, which in consequence is darkened above them; asci clavate; sporidia lanceolate, yellowish, 4–5 septate, with one of the cells longitudinally divided. On *Sparganium*, N. Wootton. Appears to be the same as specimens distributed by Dr Winter under this name, although we have seen no description. Sporidia 0·035 × 0·01 mm., the divided cell usually broadest.'

There is no record of the publication of a description by Auerswald. Saccardo (1883) compiled Cooke's description as *Leptosphaeria clara* (Cooke & Auersw.) Sacc., although he noted in his description 'loculo uno longitudinalita diviso (teste Cooke)'. He also observed that specimens sent by Winter under the name *L. clara* contained a *Didymella*, which was confirmed by Berlese (1894). The Winter specimen referred to by Cooke is in Herb. Kew labelled 'Herbarium von Georg Winter. Leptosphaeria clara Awd. Leipzig: Corewitz. Carex acuta. 7.7.1866. leg Auerswald', and also bearing the stamp of Cooke's Herbarium. Unfortunately, preparation revealed only immature specimens and no spores.

There is no specimen on *Sparganium* in the *Leptosphaeria clara* folder in Herb. Kew. However, there are various other specimens bearing Cooke's Herbarium stamp:

1. *Sphaeria clara* Awd. on glumes of *Festuca*, Neatishead. Dec. /76, labelled in Cooke's handwriting. This specimen contained perithecia of *Pleospora vagans*.

2. Herbarium von Georg Winter. *Leptosphaeria clara* Awd. Leipzig. Mai 1871. leg. G. Winter. Perithecia of *P. vagans* were also found on this specimen.

3. *Sphaerella microspora*. Rab. F. E. 1646 in Cooke's handwriting. This specimen bears an ink drawing of four spores each with 5 transverse septa and one with a single longitudinal septum. *Pleospora vagans* perithecia were found on this specimen.

In the same folder are two loose drawings by Cooke, one of four spores, each with five transverse and a single longitudinal septum labelled 'clara' and another with four 2-celled spores of the *Didymella* type labelled 'clara' Winter.

It thus seems likely from Cooke's description, drawings and specimens that his conception of *Sphaeria clara* Auersw. was *Pleospora vagans* Niessl, which antedates Cooke's description. It is possible that this was not the fungus that Auerswald intended to name, for according to Saccardo, Berlese and Cooke's own drawings a *Didymella* was present on the Winter specimens. However, since Auerswald's name was not validly published, the specimen on *Sparganium* from North Wootton is the type specimen. It is unfortunate that this specimen is missing, but the specimen on *Festuca* is authentic. It is therefore proposed that the name *Leptosphaeria clara* (Auersw. ex Cooke) Sacc. be rejected as a synonym of *Pleospora vagans* Niessl.

It is interesting to note that in the *P. sparganii* folder (labelled by Cooke) in Herb. Kew is a specimen labelled in Cooke's handwriting of 'Sphaeria on *Sparganium* N. Wootton 19'. This is possibly the type specimen of *Pleospora sparganii* Cooke (*Grevillea*, **19**, 8), and later named *P. vagans* var. *sparganii* by Berlese, 1900. Examination of the specimen confirms Berlese's disposition of the fungus.

(4) **Phomatospora dinemasporium** sp.nov. (Fig. 5)

Several collections have been made of a *Phomatospora* which is the perfect state of *Dinemasporium graminum* (Lib.) Lév.

The description below is of a collection on *Agrostis stolonifera* (Herb. Sheffield no. 1163):

Mycelium hyaline to pale brown, 1–2μ wide, penetrating parenchymatous and lignified tissues, associated with a conspicuous darkening of the epidermis around the perithecia, which becomes raised, black and shining. *Perithecia* subepidermal, on leaf sheaths and stems, singly or in groups, between the veins, globose or elongated parallel to the stem,

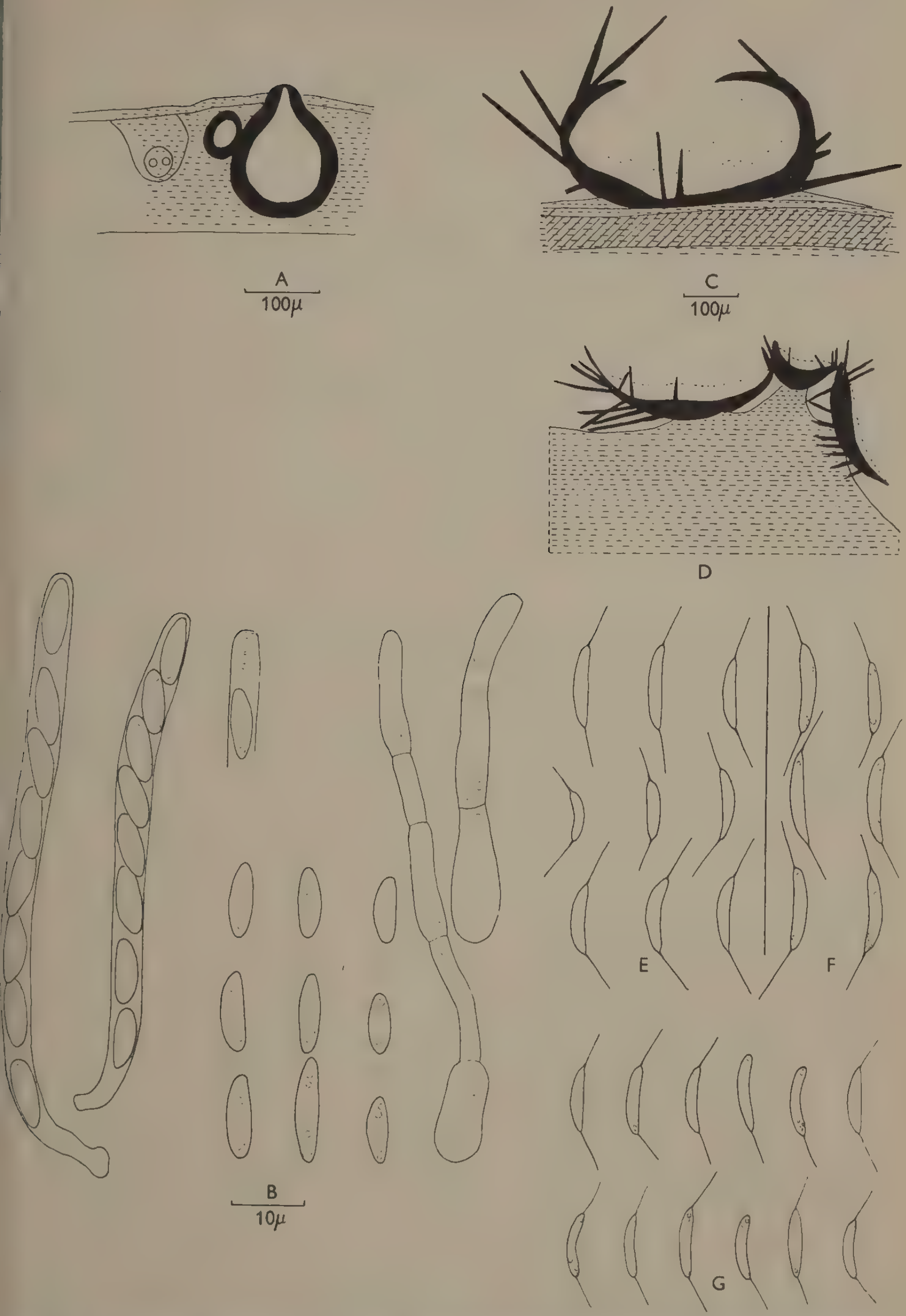

Fig. 5. *Phomatospora dinemasporium.* A, T.S. leaf sheath and perithecium; B, asci and ascospores; C, T.S. stem and conidial pustule; D, section of oat agar culture derived from a single ascospore, with conidial pustules; E, conidia from culture; F, conidia from host; G, conidia from Libert's Pl. Crypt. Ardeunn. Exs. no. 348. C, D to same scale; B, E, F, G to same scale.

120–300 μ in diameter, wall 6–15 μ thick composed of brown elongate polygonal cells; ostiole inconspicuous. *Asci* 4–8-spored, narrow, cylindrical, short-stalked, rounded above, wall single, 68–84 × 4–5 μ. *Ascospores* typically uniseriate (rarely sub-biseriate) narrowly elliptical to spindle-shaped or slightly inequilateral, hyaline, smooth, biguttulate 9–16 × 3–4 μ. Paraphyses were not seen.

The ascospores germinated readily on the surface of maize extract agar or in water drops on a microscope slide. Appressoria were not seen. Germinating ascospores were transferred to oat agar slopes and produced orange-brown colonies with little aerial mycelium. In 2-month-old cultures black setose pustules were found, bearing conidia. The pustules are single or in clusters, and may be up to 2 mm. in diameter. Each pustule consists of a saucer-shaped receptacle composed of dark thick-walled cells about 5 μ wide, surrounded by thick-walled septate, tapering, pointed black bristles up to 250 μ long and 4–10 μ wide at the base. The receptacle is lined by a palisade of hyaline conidiophores, branched or unbranched, ending in phialides. The conidia are allantoid, hyaline, smooth, and bear a single bristle at each end, measuring up to 10 μ long. The body of the conidium measures 8–12 × 1·5–2 μ. Bristles were not found on conidia still attached to their conidiophores, and are possibly formed later.

Similar conidial pustules were collected with the perithecia, growing on the nodes, leaf sheath or stem single or in clusters, varying in size from 0·2 to 1·5 mm. They develop from a mycelium completely filling the host tissues beneath the pustule, then forming a surface hyaline mat, from which the black setae arise. The conidia resemble those described above and measure 8–13 × 1·5–2 μ. Cultures prepared from single conidia matched very closely the cultures described above derived from ascospores.

Table 4. *Dimensions (in μ) of asci, ascospores and conidia of* Phomatospora dinemasporium

Herb. Sheffield no.	Date	Host	Asci	Ascospores	Conidia from culture
237*a*	18. iii. 50	*Dactylis glomerata*	66–80 × 4–5	9–10 × 2–2·5	—
242	26. vi. 49	*Phalaris arundinacea*	70–92 × 4–5	10–12 × 2·5–3	—
246	31. v. 49	*Agropyron repens*	100–122 × 4–5	11–16 × 2–3·5	7–14 × 1–2
393	29. v. 50	*Poa trivialis*	60–80 × 4–5	9–12 × 2·5–3	—
1163	5. iii. 54	*Agrostis stolonifera*	68–84 × 4–5	9–16 × 3–4	8–12 × 1·5–2
1172	18. x. 52	*Arrhenatherum elatius*	50–74 × 4–6	9–12 × 2·5–3	—
1176	17. v. 54	*Festuca rubra*	70–78 × 4–5	8–10 × 2–3	—
1221	28. x. 50	*Dactylis glomerata*	64–80 × 4–5	9–12 × 2·5–3	—
1311	12. ii. 51	*D. glomerata*	60–75 × 4–4·5	9–12 × 2–3	8–12 × 1·5–2
1337*a*	16. iv. 52	*D. glomerata*	62–88 × 4–5	8–10 × 3–4	—
1377	28. viii. 54	*Phalaris arundinacea*	64–94 × 4–5	8–13 × 2·5–3	8–14 × 1·5–2
1391	16. ix. 54	Cereal stubble	80–84 × 4–5	10–13 × 3–4	6–12 × 2–2·5
1449	26. x. 54	*Zerna erecta*	66–76 × 4–5	8–12 × 2–2·5	—
1450	26. x. 54	*Agropyron repens*	50–70 × 4–5	8–12 × 2·5–3	—

Perithecia have been collected on various grasses, and appear to be most common on old fallen stems lying on the ground in damp places. Table 4 shows the range of size of asci and ascospores, and of conidia produced in cultures on oat agar from some of these collections.

The conidia of the fungus belong to the form genus *Dinemasporium*, and many collections have been made of the conidial state on various grasses, sometimes in association with the perithecia. Conidia have been collected on the following hosts: *Agropyron repens*, *Agrostis stolonifera*, *Alopecurus pratensis*, *Arrhenatherum elatius*, barley stubble, *Brachypodium pinnatum*, *Dactylis glomerata*, *Deschampsia caespitosa*, *Festuca rubra*, *Holcus mollis*, *Juncus maritimus*, *Molinia caerulea*, *Phalaris arundinacea*, *Phleum pratense*, *Phragmites communis*, *Poa* sp. and wheat stubble, and are found throughout the year. They are most common on stem bases and fallen stems in damp places, and appear to colonize both freshly dead and old tissues.

Most of these collections bear conidia $8–14 \times 1·5–2\mu$, but the overall dimensions are $5–16 \times 1–2·5\mu$. In some collections (1221*b* on *Dactylis glomerata*, 1176*b* on *Festuca rubra*, 1448*a* on *Brachypodium pinnatum*) individual pustules were found in which the conidia lacked bristles. However, an examination of two adjacent pustules of specimen no. 1448 showed that one pustule contained spores bearing bristles, whilst the other bore conidia of the normal type. In another collection (1447 on *Dactylis glomerata*) 38 out of a sample of 116 spores examined (30·5 %) lacked bristles.

The conidia obtained from the *Phomatospora* ascospores, and the collections of conidia discussed above match descriptions of *Dinemasporium graminum* (Lib.) Lév. Léveillé (1847) erected the genus *Dinemasporium* with *D. graminum* as the type, citing the following synonyms and exsiccati: '*Peziza strigosa*, Fr. *Obs. myc.* 2, p. 304. S.M. 24, p. 103.—*Vermicularia graminum*, Lib. exsicc., No. 348—*Excipula graminum* Corda, *Icon. fung.* 3, p. 29. tab. 5, f. 79.' An example of Libert's exsiccatum no. 348 is preserved in the Herb. Kew and consists of three pieces of grass leaves bearing the characteristic black saucer-shaped pustules containing hyaline and typically biciliate spores measuring $8–11 \times 1·5–2\mu$, with bristles $6–10\mu$ long (see Fig. 5 G). Libert's specimen thus matches the collections and cultures described above.

Fries (*Systema mycologicum*, **2**, 103) cites *Exsiccatum* no. 136 as an example of *Peziza* (*Excipula*) *strigosa*. Examination of this exsiccatum from the Herb. Kew (Scleromycetae Sueciae no. 136) confirms Léveillé's citation of this fungus as synonymous with Libert's specimens no. 348. I regard both these specimens as typical *Phomatospora* conidia.

Karsten (1884) described *D. graminum* s.s. *strigosulum*, 'A typo recedit spermatiis minoribus (longit 9–12 mm.) crassit 2–3 mm. setulisque 6–8 mm. longis utrinque acutis. In culmis foliisque emortuis *Secalis cerealis*, *Poae* et *Phragmitis communis* circa Mustiala non rarum.'

Three specimens which are probably those cited by Karsten were examined:

1. Specimen labelled in Karsten's handwriting—*Dinemasporium strigosulum*. Mustiala ad caul. Secal. cereal. 4 Jan. 66.

The packet has been relabelled = *Dinemasporium* Lév. var. *strigosulum* Karst. and bears a sketch of a few spores, but these show no bristles. The specimen consists of four pieces of straw bearing dark flattened pustules with black margins and pale yellow disks. No setae were found around the pustules. The hymenium contains numerous branched sporophores bearing cylindrical hyaline spores with rounded ends, but lacking bristles, measuring 8–12 × 2 μ.

This specimen is clearly not a *Dinemasporium*.

2. Specimen labelled—*Polynema strigosum* Fr. f. *Arundinis*. Mustiala ad Phragm. P. A. Karsten 22 May 1866.

The packet has been relabelled *Dinemasporium graminum* Lib. (Lév). Sacc S. F. XI. 560, and also bears a sketch of two typical *Dinemasporium* spores. The specimen consists of pieces of *Phragmites* stem and leaf sheaths bearing *Dinemasporium* pustules, with spores 12–17 × 2 μ, and bristles up to 15 μ long. It is probably best referred to *D. graminum*.

3. Specimen labelled—*Polynema strigosum* Mustiala 15 Apr. 1866.

The packet has been relabelled *Dinemasporium graminum* Lév. W.N., bears drawings of spores lacking bristles. The specimen consists of numerous pieces of grass leaf bearing black pustules not surrounded by setae. The spores are subhyaline, cylindrical, tapering at the ends, but lacking bristles. The specimen is not a *Dinemasporium*.

From an examination of these specimens from the Karsten Herbarium there is no foundation for maintaining *D. graminum* var. *strigosulum*. The only specimen which can be certainly identified with this name is not even a *Dinemasporium*. The collection on *Phragmites* (2) whilst undoubtedly a *Dinemasporium*, bears spores which are slightly larger than the Libert specimen cited by Léveillé. It is probable that collections cited under this name should be identified as *D. graminum*.

Phomatospora dinemasporium sp.nov. (Fig. 5)

Mycelium hyalinum vel brunneum, 1–2 μ latum, partes parenchymaticas et ligneas penetrans et epiderma nigrificans circa perithecia, atque ita prominens et polita fit. Perithecia sub epidermida crescentia, in culmis vaginisque, aut singula aut plura, inter venas, globosa vel elongata, 120–300 μ diametra quorum muri 6–15 μ lati sunt, et ex cellis elongatis brunneisque compositi, ostiola inconspicua. Asci 4–8 sporas continentes, angusti, cylindricales, cum brevibus stipitibus, membranis unis, supra rotundati, 68–84 × 4–5 μ.

Ascosporae uniseriatae, plerumque (nonnumquam sub-biseriatae) tenuatim ellipticales, vel fusoideae vel inequilaterales, hyalinae, glabrae, biguttulatae, 9–16 × 3–4 μ. Paraphyses non visae sunt.

Status conidicus *Dinemasporium graminum* est. In culmis multorum graminum. Specimen No. 1163 Mycological Herbarium, University of Sheffield typus est.

It is a pleasure to acknowledge help from the following persons who allowed me to examine specimens in their keeping: Dr C. J. Hickman, Prof. J. R. Matthews, Prof. W. B. Robyns and Sir Edward J. Salisbury. I am also indebted to Dr R. Sprague, who identified material sent to him, and to Mr A. O. Hulton of the Classics Department, Sheffield University, for the Latin diagnosis. This work was in part financed by the University of Sheffield Research Fund.

REFERENCES

BERLESE, A. N. (1894). *Icones Fungorum*, I. Patavii.

BERLESE, A. N. (1900). *Icones Fungorum*, II. Patavii.

BISBY, G. R. & MASON, E. W. (1940). List of Pyrenomycetes recorded for Britain. *Trans. Brit. mycol. Soc.* **24**, 127–243.

HUGHES, S. J. (1949). The perithecia and pycnidia of *Leptosphaeria nigrans*. *Trans. Brit. mycol. Soc.* **32**, 63–68.

GROVE, W. B. (1937). *British stem- and leaf-fungi* (*Coelomycetes*), **2**. Cambridge University Press.

KARSTEN, P. A. (1872). Fungi in insulis Spetsbergen et Beeren Eiland collecti. *Öfvers. VetenskAkad. Förh., Stockh.*, **2**, 91–108.

KARSTEN, P. A. (1884). Fragmenta mycologica. X. *Hedwigia*, pp. 20–22.

LÉVEILLÉ, J. H. (1846). Description des champignons de l'Herbier du Muséum de Paris. *Ann. Sci. nat.*, Ser. 3, **5**, 249–304.

MÜLLER, E. (1950). Die schweizerischen Arten der Gattung *Leptosphaeria* und ihrer Verwandten. *Sydowia*, **4**, 185–319.

NIESSL, G. (1876). Notizen über neue und kritische Pyrenomyceten. *Verh. naturf. Ver. Brünn.* **14**, 165–218.

OUDEMANS, C. A. J. A. (1919). *Enumeratio systematica fungorum*, **1**.

SACCARDO, P. A. (1879). *Michelia*, **1**.

SACCARDO, P. A. (1883). *Sylloge Fungorum omnium hucusque cognitorum*, **2**.

SIMMONS, E. G. (1952). Culture studies in the genera *Pleospora*, *Clathospora* and *Leptosphaeria*. *Mycologia*, **44**, 330–365.

SPRAGUE, R. (1935). *Wojnowicia graminis* as a very weak secondary parasite of winter cereal crops. *Phytopathology*, **25**, 405–415.

SPRAGUE, R. (1943*a*). The status of *Septoria alopecuri* and related species. *Mycologia*, **35**, 209–213.

SPRAGUE, R. (1943*b*). The genus Phaeoseptoria on grasses in the Western Hemisphere. *Mycologia*, **35**, 483–491.

SPRAGUE, R. (1950). *Diseases of cereals and grasses in North America*. New York.

TRAIL, J. W. H. (1889). Fungi of Inverary and its vicinity observed in September, 1888. II. Micromycetes. *Scot. Nat.* (N.S.) **4**, 57–76.

WEBSTER, J. (1956). Ecology of fungi decomposing cocksfoot culms. (In the Press.)

WEHMEYER, L. E. (1949). Studies in the genus *Pleospora*. I. *Mycologia*, **41**, 565–593.

WINTER, G. (1887), in Rabenhorst's *Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz*, Bd. **1**, Abt. II. Ascomyceten.

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THE BASIDIOMYCETES OF SKOKHOLM ISLAND

XIII. *ECHINOTREMA CLANCULARE* GEN. ET SP.NOV.

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(With 1 Text-figure)

One way to find unusual species of fungi is to search in unusual habitats. Every now and again something turns up which makes one wonder how much is really known about the habits and distribution of the higher fungi. The subject of this note is a case in point.

On the morning of 17 July 1954, a party of ornithologists at the Skokholm bird observatory went out to the Neck peninsula to dig for puffins (*Fratercula arctica grabae* (Brehm.)). They reported finding in some of the disused rabbit-holes in which they had been searching large amounts of a whitish fungus. I asked them, if they should find any more, not to throw it away but to bring me a specimen. In the evening they brought a quantity of whitish growth, of which a part is now deposited in the Kew Herbarium. It proved on examination to be a hitherto unrecorded species of Basidiomycete, which I shall now describe.

Receptacle resupinate, widely but irregularly effused, thin, of a floccose consistency; dingy whitish, smell distinctive.

Hymenophore sistotremoid, composed of parallel sinuous plates up to 2·5 cm. long by 5 mm. broad by 1 mm. thick, interstices about 1 mm. wide in the minimum direction (Fig. 1 *a*). In the material I saw there was no sterile margin of the receptacle. Trama (as whole fungus) composed of uniform hyphae without typical clamp-connexions, from 2 to 3 μ broad, very distinct, hyaline.

Hymenium composed of rather loose clusters of urniform *basidia*, very variable but averaging 15 μ long by 5 μ at the widest region near the base, with 3–6 *sterigmata* diverging from the apex (Fig. 1 *b*). *Subhymenium* wanting.

Spores globose, 4 to 5 μ in diameter, hyaline, strongly echinulate. *Cystidia* or other specialized endings wanting.

The smell referred to was just that of a roomful of agarics on the day after a fungus foray, but not strong enough to be unpleasant. The type material came from the underside of a tussock of *Armeria* which was not a rabbit burrow, but the latter are also inhabited by the fungus.

This fungus does not appear to fit into any existing genus, but it can be reasonably accommodated in the family Sistotremataceі. The hypochnoid hymenium is very similar to that in *Tomentella*, but the hymenium of *Sistotrema confluens* is only more compact and not to my mind radically different. It differs from *Tomentella* and other related genera in the very well-developed hymenophore, which resembles that of *Sistotrema* but is much deeper and built on a larger scale. From *Sistotrema* it differs also in the *Tomentella*-like spores. Mr D. A. Reid, who has kindly confirmed my observations on the type specimen, suggests an affinity with *Lindtneria* Pil.; but according to Bourdot & Galzin (1928) the type species *L. trachyspora* (Bourd. & Galz.) Pil. does not have typically urniform basidia, and the hymenophore is very much smaller and *Poria*-like. There seems therefore no help but to erect a new genus for this species, for which I propose the name *Echinotrema clanculare*.

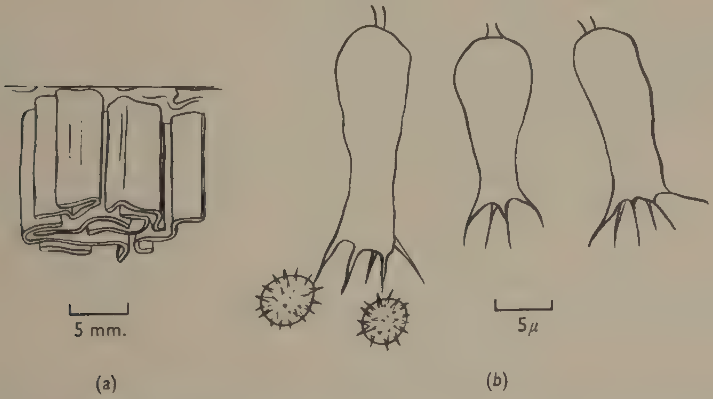

Fig. 1. *Echinotrema clanculare* gen. et sp.nov. *a*, diagrammatic view of portion of hymenophore, exposed to show depth; *b*, basidia and spores.

The Sistotrematacei, if they be allowed to be a natural group, are evidently a relict family, of which we have but a small selection of genera and species, out of a number perhaps anciently much larger. Such a species as this may therefore be of limited distribution and rare occurrence. On the other hand, there would seem to be scope for fungi adapted for life in the excavations of fossorial animals and distributed zoochorically by them, and this may be such a one. If it be the rabbit (*Oryctolagus cuniculus* (L.)) which is its vector, it is probably rare, for the digging up of rabbit burrows is a regular practice, and a common fungus in such burrows would not have escaped detection so long. But these burrows in the Armerietum on Skokholm Island are also occupied by puffins (*Fratercula arctica grabae* (Brehm.)) and shearwaters (*Puffinus p. puffinus* (Brünn.)), either of which might determine its distribution, and whose dwellings are rarely visited by mycologists. It would be worth while to look out for this interesting species in other colonies of these birds, and those of similar habits.

Diagnosis

Echinotrema gen.nov. est fungus basidiomyces basidiis continuis sertulatis in hymenio laxo sine subhymenio et urniformibus, hymenophorum ferens ex denticulis verticaliter dependentibus complanatis sinuosisque compositum et basidiocarpi partem maiorem sistentem, receptaculo resupinato ex hyphis uniformibus constructo, sporis hyalinis echinulatis. Species typus est *Echinotrema clanculare* quae subtus describetur. Nomen applicatur propter spora *echin*ata atque hymenophorum Sisto*tremat*i simile.

Echinotrema clanculare sp.nov. (Fig. 1) est Echinotrema albidum odore agaricalium exsiccantum, hymenophoro usque ad 2·5 cm profundo, basidiis 3–6 sterigmata divaricata ferentibus, sporis 4–5μ diam. globosis, hyphis 2–3μ latis, unquam distinctis, fibulis genuinis rarissimis sive nullis. Habitat in locis cavis sub detritu Armeriae plantarumve similium, praecipue in antriculis Oryctolagi ubi aves maritimae habitaverunt, ad insulam Cambriae quae Skokholm vocatur. Specimen typus in herbario regale Kewense depositus est. Sic nominatur propter habitum clancularem.

REFERENCE

Bourdot, H. & Galzin, A. (1928). *Les Hymenomycètes de France.* Paris: Lechevalier.

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A SURVEY OF ANIMAL MYCOSES IN BRITAIN: MYCOLOGICAL ASPECTS

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As a result of a two-year Survey of fungi associated with disease in farm animals in Britain, approximately 1200 isolates of fungi from morbid material were identified and classified in 129 species (see Table 1, p. 373). Twenty-eight species were considered to have been pathogenic or potentially pathogenic and to have been causally involved in approximately 300 cases.

More than half the isolates belonged to five genera (*Aspergillus*, *Absidia*, *Candida*, *Trichophyton* and *Penicillium*) and there was a preponderance of two thermophilic species, *Aspergillus fumigatus* (19·6% of all isolates) and *Absidia ramosa* (8·4%).

While the data provide little conclusive evidence that the fungi associated with one animal are more diverse than those associated with another, either for the whole animal or for the skin alone, they do suggest that the skin harbours a more diverse range of fungi than do other sites of the animal body, and they illustrate the importance of yeasts as components of the mycoflora of the respiratory organs, of the alimentary canal and of milk.

Evidence was obtained that mouldy hay may be an important source of fungi potentially pathogenic for animals.

An interesting feature of the Survey was the frequent isolation of aerobic Actinomycetes of uncertain pathogenic status from both the skin and internal organs.

The paper includes an annotated list of the pathogenic or potentially pathogenic Eumycetes and Actinomycetes, together with a host index (p. 384).

INTRODUCTION

In 1951 the Agricultural Research Council agreed to sponsor a Survey, by veterinary officers and mycologists, of the fungi associated with disease in farm animals. Arrangements were made for the collection of material by Veterinary Investigation Officers stationed at the sixteen Veterinary Investigation Centres in England and Wales, and for the mycological examinations to be carried out in the Department of Botany, University College, Exeter. Additional specimens were received from veterinary practitioners, university veterinary schools, and from the Veterinary Investigation Departments in Scotland. Material from nearly 700 cases of mycotic or suspected mycotic infections was examined for fungi during the period January 1952 to December 1953; the samples received comprising 392 cultures (either primary cultures or subcultures made at the Veterinary Investigation Centres), 262 specimens of morbid tissues, and nineteen samples of hay and fodder. From this material 1129 isolates of fungi and Actinomycetes were identified and classified in 129 species (see Table 1). Twenty-eight of the species of fungi were considered to be pathogenic or potentially pathogenic, and to have been causally involved in approximately 300 cases.

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An account of the general and epidemiological aspects of the Survey has already been published (Ainsworth & Austwick, 1955). This paper records mycological aspects of the results.

METHODS

Microscopical examination of morbid tissues and cultures

Skin and hair samples were microscopically examined in 20% aqueous potassium hydroxide solution which, on gentle warming, gave rapid clearance and softening of the tissues without affecting any fungus elements present. Lactophenol (with or without cotton blue) proved useful in making semi-permanent preparations from such samples and was also used for the routine examination of cultures.

For the direct examination of other tissues (lung, liver, etc.), whether fresh or preserved, mounting in water or saline solution and 20% potassium hydroxide, supplemented when necessary with stained smears, was found to be satisfactory.

A large collection of fixed and preserved material from mycotic conditions was accumulated, but there was little opportunity for its detailed histological examination. A representative selection of the tissue samples was, however, sectioned and stained by various techniques; excellent differentiation of fungus from animal tissue being obtained by the use of the periodic acid-Schiff reaction as described by Kligman & Mescon (1950).

Methods of isolation

At the Veterinary Investigation Centres, where special mycological media were not in routine use, many isolates of fungi were obtained during bacteriological examinations. At Exeter normal mycological procedure and a number of specially developed techniques were used for making isolations from infected tissues.

Ringworm samples

Direct plating of infected hair from cats and dogs gave good results, but the rapid growth of saprophytes from microscopically positive bovine and equine samples invariably prevented the isolation of the dermatophytes. Various methods to overcome this difficulty recommended by other workers, including the use of Littman's ox gall agar (Littman, 1947) and the dilution technique of Hoerlein (1945), were tried but with indifferent success. This led to the development of a method designed specifically for the isolation of *Trichophyton verrucosum* var. *discoides* from cattle hair, but which proved equally useful in isolating *T. equinum* from horses. The method which has been described in detail by Austwick (1954) enabled almost every microscopically positive sample to be confirmed by culture and shortened the time for provisional identification of the cattle ringworm fungus from 4 weeks to 1 week. Nutrient agar supplemented with antibiotics was used in this technique and it was latterly adopted as the routine isolation medium for dermatophytes. All the ringworm fungi encountered made rapid and characteristic growth on this medium, from which they were transferred to a Sabouraud *milieu d'épreuve* for final identification.

Internal organs, etc.

Lungs, viscera or other tissues were plated direct or after dilution, using malt or nutrient agar, with or without the addition of antibiotics. Aspergillotic nodules, for example, when plated whole on malt agar and incubated at 35° C., usually gave a prolific growth of the pathogen within 48 hr. These media were also found satisfactory for making isolations from poultry crops, from cases of suspected moniliasis, from mastitis milk, and from foetal stomach contents. Yeasts grew most readily on beerwort agar, which was also used to free them from bacterial contamination, but the addition of penicillin and streptomycin to malt agar proved a more convenient technique for this purpose.

Hay and fodder

For hay and fodder samples direct examination and dilution plating with malt agar were employed.

Terminology

In this paper the terms 'case' and 'isolate' are used as in the account of the general aspects of the Survey. A 'case' sometimes involved a single animal, at other times it was an outbreak involving more than one animal, whilst the record of a species from one case was treated as one 'isolate' irrespective of the number of times it was observed.

RESULTS

The fungi associated with domestic animals

Very few attempts have been made to enumerate the fungi associated with animals in contrast to the many studies of phytopathogenic, wood-destroying and soil fungi, and the lists of fungi associated with animals hitherto available show a preponderance of pathogenic species. The 1200 isolates identified during the Survey are believed to constitute one of the longest well-documented series of pathogens and saprophytes from animals. They do not, however, for a number of reasons, allow any but the most tentative generalizations to be made. First, they are too few. The number of species recorded from any animal continued to rise until 100–150 isolates had been named, when the number of new records for each animal fell off rapidly. Secondly, there is a pathogenic bias. Almost all the material examined originated from animals suffering from mycotic or suspected mycotic infections, and many of the non-pathogenic fungi recorded would normally have passed unnoted as saprophytes. The number of saprophytes in primary cultures depends, among other factors, on the skill of the mycologist, the technique employed, the characteristics of the morbid materials, and the ease with which the particular pathogen being sought can be recognized, e.g. the isolation of a dermatophyte is usually taken as evidence that the dermatophyte was present as a pathogen, and so the identity of any associated moulds is of less interest than in isolations from conditions of unknown etiology. It is, however, believed that most of the fungi recorded were derived from the animals and their environment and were not laboratory contaminants. Thirdly, the majority of the isolates received from Veterinary Investigation Departments were, as already mentioned, obtained during routine bacteriological examinations; they were thus of species that will grow on diverse bacteriological media and tolerate the conditions of incubation favourable to pathogenic bacteria.

In spite of these sampling defects it is of some interest to consider the isolates in relation to their taxonomic distribution and the different animals and sites involved.

Taxonomic distribution of the isolates

In Table 1 the 1100 isolates are distributed according to species. In Table 2 they are summarized according to the major classes of fungi, from which it is clear that mycelial Fungi Imperfecti accounted for more than half the isolates and for approximately half the species. Yeasts, of all three families, and Phycomycetes comprised the majority of the remaining isolates and species (36·7 and 42·7 %, respectively). Two isolates were made of a Basidiomycete which was provisionally identified as *Stereum hirsutum*, and one of a colourless alga, *Prototheca portoricensis*.

More than half the isolates were distributed in five genera: *Aspergillus* (324), *Absidia* (132), *Candida* (97), *Penicillium* (84), and *Trichophyton* (55). Half the genera were each represented by one species only, and the greatest number of species for any one genus was twelve (for *Candida*). The nine most frequently recorded species (Table 3) accounted for 50·9 % of all isolates and 56 species were recorded once each (including 26 species incompletely identified).

A surprising result was the preponderance of two thermophilic species, *Aspergillus fumigatus*, which accounted for 19·6 % of all isolates, and *Absidia ramosa*, 8·4 %. *A. fumigatus* is regarded as comparatively uncommon in soil (Warcup, 1951), but its frequent occurrence in maturing compost (Eastwood, 1952) may partly account for its presence in the environment of farm animals. The species of *Absidia* which constituted the dominant fungi in cultures from skin scrapings, are also rarely reported. The regular occurrence of *Aspergillus* spp. at nearly four times the frequency of those of *Penicillium* is also of interest as reversing the position of these two genera as they have been observed from soil.

Only four of the isolates of *Penicillium* were thought to have been of etiological importance; only two occurred as single isolates (i.e. as the only fungus isolated), and two-thirds of the total were from the skin, from hay samples, and from the lungs of fowls which had died from non-mycotic infections. In view of this only a selection of the more interesting isolates were studied and kindly named by Dr A. H. S. Brown. Similarly, not all

Table 1. *List of species*

(Genera and species are grouped alphabetically under classes, and the number of isolations from each of the nine commonest mammals and birds and from hay, etc., are given. Records of the sites on the animals, the geographical locations, and other data regarding the isolates have been preserved for future reference, together with a representative culture of each species.

Culture deposited at the: [1] Commonwealth Mycological Institute, Kew; [2] Centraalbureau voor Schimmelcultures, Baarn and Delft; [3] Forest Products Research Laboratory, Princes Risborough.

† Pathogen or suspected pathogen. * Believed to be a new British record.)

	Cattle	Horse	Sheep	Pig	Dog	Cat	Other mammals	Fowl	Turkey	Duck	Other birds	Hay, etc.	Totals
PHYCOMYCETES													
[1]*Absidia corymbifera* (Cohn) Sacc. & Trot.	29	1	1	2	.	.	3	11	1	.	.	4	52
[1]*A. ramosa* (Lindt) Lendner	58	5	1	3	1	.	1	12	1	.	.	10	92
*† *Haplosporangium parvum* Emmons & Ashburn	.	.	.	.	.	.	1	.	.	.	.	.	1
[1]*Mucor hiemalis* Wehm.	.	.	.	.	.	.	.	.	.	.	.	1	1
[1]*M. pusillus* Lindt	5	.	.	1	1	.	.	4	.	1	.	3	15
[1]*M. racemosus* Fresen.	4	.	.	3	1	.	[illegible]	3	4	.	.	1	18
[1]*Rhizopus arrhizus* Fischer	.	.	.	.	.	.	.	.	.	.	.	1	1
[1]*R. microsporus* van Tieghem	.	.	.	.	.	.	.	1	.	.	.	.	1
R. stolonifer (Fr.) Lind.	.	.	.	.	.	.	.	.	.	.	.	2	2
[1]*Syncephalastrum racemosum* (Cohn) Schroeter	.	.	.	1	.	.	.	.	.	.	.	.	1
[1]*Thamnidium elegans* Link	.	.	.	.	.	.	.	.	.	.	.	1	1
ASCOMYCETES													
[1]*Chaetomium funicola* Cooke	.	.	.	.	.	.	.	.	.	.	.	1	1
[1]*C. globosum* Fr.	1	.	.	.	.	.	.	1	.	.	.	.	2
[1]*C. indicum* Corda	.	1	.	.	1	.	.	.	.	.	.	1	3
†*Claviceps purpurea* Tul.	.	.	.	.	.	.	.	.	.	.	.	1	1
[2]*Debaryomyces kloeckeri* Guilliermond & Péju	.	.	.	.	.	.	.	1	.	.	.	1	2
[2]*Hansenula angusta* Wickerham	1	.	.	.	.	.	.	.	.	.	.	.	1
[2]*Pichia farinosa* (Linder) Hansen	5	.	.	.	.	.	.	1	.	.	.	.	6
[2]*P. membranaefaciens* Hansen	.	.	.	1	.	.	.	.	.	.	.	.	1
[2]*Saccharomyces bisporus* (Naganishi) Lodder & van Rij	.	.	.	.	.	.	.	.	.	.	.	1	1
[2]*S. cerevisiae* Hansen	.	.	.	.	.	.	1	1	1	.	.	.	3
[2]*S. fragilis* Jörg.	2	.	.	.	.	.	.	.	.	.	.	1	3
[1]*Sordaria fimicola* (Rob.) Ces. & de Not.	.	.	.	1	.	.	.	.	.	.	.	.	1
BASIDIOMYCETES													
[3]*Stereum hirsutum* (Fr.) Fr.	1	.	.	1	.	.	.	.	.	.	.	.	2
FUNGI IMPERFECTI													
Acremoniella atra (Corda) Sacc.	1	.	.	.	.	.	.	.	.	.	.	.	1
Acrostalagmus cinnabarinus Corda	1	1	.	.	.	.	.	.	.	.	.	.	2
Alternaria V. 346/3	3	.	.	.	.	.	.	.	.	.	.	.	3
[1]*Aspergillus amstelodami* (Mangin) Thom & Church	2	1	.	.	.	.	.	1	.	.	.	1	5
[1]*A. candidus* Link	.	.	.	1	.	.	.	2	.	1	.	5	9
[1]*A. carneus* (van Tieghem) Blochwitz	.	.	1	.	.	.	.	2	.	.	.	1	4
[1]*A. clavatus* Desm.	.	.	.	.	.	.	.	1	.	.	.	.	1
†[1]*A. flavus* Link	.	.	1	.	.	.	.	1	2	.	1	2	7
†[1]*A. fumigatus* Fresenius	66	4	2	8	6	4	1	75	20	9	18	6	219
A. glaucus series	2	.	.	2	5	.	.	7	.	.	.	7	23
†[1]*A. nidulans* (Eidam) Wint.	8	4	1	1	2	.	.	3	.	.	.	4	[illegible]3
†[1]*A. niger* van Tieghem	3	.	1	.	1	.	.	4	.	.	.	5	14
A. repens (Corda) De Bary	3	.	.	1	.	.	.	.	.	.	.	.	4
†[1]*A. terreus* Thom	[illegible]5	1	2	3	1	.	.	10	1	.	[illegible]	7	52
[1]*A. versicolor* (Vuill.) Tiraboschi	4	.	.	1	4	.	.	7	1	.	.	2	19
Botrytis cinerea Fr.	.	.	.	.	1	.	.	.	.	.	.	.	1
†[2]*Candida albicans* (Robin) Berkhout	3	.	.	.	1	.	.	19	13	1	2	.	39
[2]*C. brumptii* Lang. & Guerra	1	.	.	1	.	.	.	3	.	.	.	.	5
[2]*C. guilliermondii* (Cast.) Lang. & Guerra	4	.	.	.	.	.	.	2	1	.	.	.	7
[2]*C. intermedia* (Cif. & Ashf.) Lang. & Guerra	.	.	.	1	.	.	.	1	.	.	.	.	2
†[2]*C. krusei* (Cast.) Berkhout	10	.	.	1	.	.	.	4	3	.	.	1	19
[2]*C. mycoderma* (Rees) Lodder & van Rij	1	.	.	.	.	.	.	1	.	.	.	.	2
[2]*C. parapsilosis* (Ashf.) Lang. & Talice	6	.	.	2	2	.	.	1	.	.	.	.	11
[2]*C. pulcherrima* (Lindner) Windisch	1	1	.	.	.	.	.	.	.	.	.	.	2
[2]*C. rugosa* (Anderson) Diddens & Lodder	.	.	.	1	1	.	.	.	.	.	.	.	2
[2]*C. solani* Lodder & van Rij	.	.	.	.	.	.	.	1	.	.	.	.	1
†[2]*C. tropicalis* (Cast.) Berkhout	2	.	.	1	.	.	.	1	.	.	.	.	4
[2]*C. zeylanoides* (Cast.) Lang. & Guerra	3	.	.	.	1	.	.	2	.	.	.	.	6
[1]*Cephalosporium* V. 101/2	2	1	.	3	1	.	.	1	.	.	.	2	10
Cephalosporium V. 146/4	.	.	.	.	2	.	.	.	.	.	.	.	2
Cephalosporium V. 126/2	.	.	.	.	.	.	.	.	.	.	.	1	1
Cephalosporium V. 450	.	1	.	.	.	.	.	.	.	.	.	.	1
Cladosporium herbarum Fr.	.	.	.	1	4	.	.	2	.	.	.	5	12
[2]* *Cryptococcus albidus* (Saito) Skinner	.	.	.	.	.	1	.	.	.	.	.	.	1
[2]* *C. diffluens* (Zach) Lodder & van Rij	.	.	.	.	1	.	.	.	.	.	.	.	1
[2]* *C. laurentii* (Kuff.) Skinner	1	.	.	.	.	.	.	.	.	.	.	.	1
†[2]*C. neoformans* (Sanf.) Vuill.	1	.	.	.	.	.	.	.	.	.	.	.	1
[1]*Fusarium culmorum* (W. G. Sm.) Sacc.	.	.	.	.	.	.	.	1	.	.	.	1	2
[1]*F. oxysporum* sensu Snyder & Hansen	.	.	.	.	.	.	.	.	.	.	1	.	1
[1]*F. sambucinum* Fuckel forma	.	.	.	.	.	.	.	.	1	.	.	.	1
[1]*F. sporotrichioides* Sherb.	.	.	.	1	.	.	.	.	.	.	.	.	1

Table 1 (*cont.*)

	Cattle	Horse	Sheep	Pig	Dog	Cat	Other mammals	Fowl	Turkey	Duck	Other birds	Hay, etc.	Totals
Fungi Imperfecti (*cont.*)													
†*Geotrichum candidum* Link	8	.	.	4	2	.	.	4	1	.	.	.	19
[1]*Gliocladium catenulatum* Gilman & Abbott	.	.	.	.	.	1	.	.	.	.	.	.	1
[1]*Gliocladium* V. 505b.	.	.	.	.	.	1	.	.	.	.	.	.	1
†[1]*Graphium* V. 123	3	.	.	.	.	.	.	.	.	.	.	.	3
[1]*Graphium* V. 192	.	.	.	.	.	.	.	2	.	.	.	.	2
[1]*Hendersonia* V. 597/2	.	.	.	.	.	1	.	.	.	.	.	.	1
†*Microsporum canis* Bodin	.	.	.	.	6	17	.	.	.	.	.	.	23
†*M. equinum* (Delacroix & Bodin) Guéguen	.	1	.	.	.	.	.	.	.	.	.	.	1
*[2]*Mycotorula verticillata* Red. & Cif.	1	.	.	.	.	.	.	.	.	.	.	.	1
[1]*Paecilomyces varioti* Bainier	1	.	.	.	.	.	.	.	.	.	.	1	2
Paecilomyces V. 418/9	.	.	.	.	.	.	.	.	.	.	.	1	1
[1]*Papularia arundinis* (Corda) Fr.	1	.	.	.	1	2	.	.	.	.	.	.	4
[1]*Papularia* V. 359/2	.	.	.	.	.	.	.	1	.	.	.	.	1
[1]*Penicillium crustosum* Thom	.	.	.	1	.	.	.	.	.	.	.	.	1
[1]*P. cyclopium* Westling	2	.	.	.	.	.	.	.	1	.	.	4	7
[1]*P. piceum* Raper & Fennell	1	.	.	2	.	.	.	.	.	.	.	1	4
[1]*P. spinulosum* Thom	.	.	.	.	.	.	.	1	.	.	.	.	1
Penicillium spp.	15	2	.	1	12	5	.	26	2	1	1	6	71
Phoma V. 140/3	.	.	.	.	1	.	.	.	.	.	.	.	1
Phoma V. 146/1	.	.	.	.	1	.	.	.	.	.	.	.	1
Phoma V. 211/3	2	.	.	.	.	.	.	.	.	.	.	.	2
Phoma V. 234/2	.	.	.	.	.	.	.	1	.	.	.	.	1
Phoma V. 388/2	.	.	.	1	.	.	.	.	.	1	.	.	2
Phoma V. 593/5	.	.	.	.	1	.	.	.	.	.	.	.	1
*†[2]*Pityrosporum pachydermatis* Weidman	1	.	.	.	1	.	.	.	.	.	.	.	2
Pullularia pullulans (de Bary) Berkhout	2	.	.	.	3	.	.	.	.	.	.	1	6
[2]*Rhodotorula glutinis* (Fres.) Harrison var. *rubescens* (Saito) Lodder	.	.	.	.	.	.	.	.	.	1	.	.	1
[2]*R. mucilaginosa* (Jörg.) Harrison	3	.	1	.	1	1	.	2	1	.	.	.	9
[2]*Rhodotorula* V. 29	.	.	.	.	1	.	.	.	.	.	.	.	1
[1]*Scopulariopsis brevicaulis* Bainier	7	.	.	2	1	1	.	2	.	.	.	4	17
[1]*Scopulariopsis* V. 230/2	.	1	.	.	.	.	.	.	.	.	.	.	1
[2]*Sporobolomyces roseus* Kluyver & van Niel	2	.	.	.	.	.	.	.	.	.	.	1	3
[2]*Sporotrichum* V. 626/3	.	.	.	1	.	.	.	.	.	.	.	.	1
[1]*Stemphylium* V. 128/2	1	.	.	.	.	.	.	2	.	.	1	.	4
[1]*Stysanus microsporus* Sacc.	.	.	.	.	.	.	.	.	.	.	.	2	2
[1]*S. stemonites* (Pers. ex Fr.) Corda	.	.	.	1	.	.	.	.	.	.	.	.	1
[2]*Torulopsis candida* (Saito) Lodder	5	.	.	4	1	.	.	5	1	.	.	.	16
[2]*T. famata* (Harrison) Lodder & van Rij	3	.	.	1	1	1	.	5	2	1	.	2	16
[2]*T. glabrata* (Anderson) Lodder & Vries	.	.	.	1	.	.	.	.	.	.	.	.	1
[2]*Torulopsis* V. 250	.	.	.	.	.	.	1	4	3	.	.	.	8
[2]*Torulopsis* V. 147/2	1	.	.	.	.	.	.	.	.	.	.	.	1
[1]*Trichoderma köningi* Oudemans	2	.	.	.	.	.	.	.	.	.	.	2	4
[1]*T. viride* Fr.	.	.	.	2	.	.	.	.	.	.	.	1	3
†*Trichophyton equinum* Gedeolst	.	5	.	.	.	.	.	.	.	.	.	.	5
†*T. mentagrophytes* (Robin) Blanchard	.	.	.	.	5	2	.	.	.	.	.	.	7
†*T. verrucosum* Bodin var. *discoides* (Sabouraud) Georg	41	1	.	.	.	.	.	.	.	.	.	.	42
[1]*Trichosporium cerealis* (Thum.) Sacc.	1	.	.	.	.	.	.	1	.	.	.	3	5
†[2]*Trichosporon cutaneum* (de Beurm., Gougerot & Vaucher) Ota	.	.	.	2	2	.	.	.	1	.	.	.	5
[1]*Trichothecium roseum* (Pers.) Sacc.	1	.	.	2	3	.	.	.	.	.	.	2	8
[1]*Tritirachium album* Limber	.	.	.	.	.	1	.	.	.	.	.	.	1
Verticillium V. 310/9	1	.	.	.	.	.	.	.	.	.	.	.	1
V. 9/7	.	.	.	.	1	.	.	.	.	1	.	.	2
V. 15/5	1	.	.	.	.	.	.	.	.	.	.	.	1
V. 208/4	.	.	.	.	.	.	.	1	.	.	.	.	1
V. 270/3	1	.	.	.	.	.	.	.	.	.	.	.	1
V. 278/3	.	.	.	.	.	.	.	.	.	.	.	2	2
V. 310/11	1	.	.	.	.	.	.	.	.	.	.	.	1
V. 359/4	.	.	.	.	.	.	.	1	.	.	.	.	1
V. 373/1	.	1	.	.	.	.	.	.	.	.	.	.	1
V. 451/1	.	.	.	.	1	.	.	.	.	.	.	.	1
V. 496	1	.	.	1	.	.	.	.	.	.	.	1	3
V. 576/9	.	.	.	.	.	.	.	.	1	.	.	.	1
V. 650/4	.	.	.	.	.	.	.	1	.	.	.	.	1
Actinomycetes													
†*Actinomyces bovis* Harz	1	.	.	.	.	.	.	.	.	.	.	.	1
†*Nocardia* spp.	.	.	.	1	.	.	1	.	.	.	.	.	2
†*Streptomyces* spp.	21	4	2	13	2	1	.	4	.	1	1	.	49
Totals	392	36	13	82	85	40	11	250	62	18	27	113	1129
ALGAE													
Chlorophyceae													
*†[2]*Prototheca portoricensis* Cif., Ashf. & Dalmau	1	.	.	.	.	.	.	.	.	.	.	.	1

Note. According to Diddens & Lodder (1942), in *Die anaskosporogenen Hefen*, 2, *Mycotorula verticillata* Red. & Cif. belongs to the genus *Hyalodendron* Diddens.

the *Aspergillus glaucus* series isolates were identified, but with the help of Mr George Smith all the other isolates in this genus were named. The entries under *Phoma* in the list appear to represent distinct species.

Table 2. *Taxonomic distribution of the species*

		No. of isolates			No. of species			
					Deter.		Indet.	
Phycomycetes				185	11		—	
Fungi Imperfecti	Mycelial	674		862	41	66	33	36
Yeasts	Yeasts	188	204		25		3	
Ascomycetes	Yeasts	16		24	6	11	—	
	Mycelial	8			5			
Basidiomycetes				2	1		—	
Actinomycetes				52	1		2	
				1125	90		38	
					128			

Table 3. *List of the most frequently isolated species*

Species	No. isolates
Aspergillus fumigatus	219
Absidia ramosa	92
A. corymbifera	52
Aspergillus terreus	51
Trichophyton verrucosum var. *discoides*	42
Candida albicans	39
Aspergillus glaucus series	32
Microsporum canis	23
Aspergillus nidulans	23
Total	573

Number of species associated with different animals

Table 4 shows that the data provide little conclusive evidence that the fungi associated with one animal are any more diverse than those associated with another either for the whole animal or for the skin alone. The figures do perhaps suggest that cattle harbour a wider range of species than other animals and support the general impression that more saprophytic fungi are associated with dogs than with cats, but because the number of species from a particular animal increased rapidly until 100–150 isolates had been

Table 4. *Number of species associated with different animals*

	All sites			Skin only	
Animal	No. isolates	No. species	Percentage species from the one animal only	No. species	Percentage species from the one animal only
Cattle	392	60	30·0	33	27·3
Horse	30	17	35·2	16	18·8
Pig	79	38	15·8	23	30·2
Dog	80	42	19·0	40	32·6
Cat	37	13	30·8	13	30·8
Fowl	230	48	16·7	19	26·4
Turkey	60	20	5·0	3	33·3

recorded such comparisons must be treated with reserve. Of the twenty-eight species peculiar to one animal alone, only five were recorded more than once: *Trichophyton equinum* (which is host specific, 5 times), *Graphium* V. 123 (3 times), *Graphium* V. 192, *Phoma* V. 211/3 and *Saccharomyces fragilis* (twice each).

Number of species associated with different sites

Table 5 summarizes data regarding the fungi associated with six different sites on nine animals. These figures suggest that the skin yields a more diverse range of fungi than do other sites of the animal body and they illustrate the importance of yeasts as components of the mycoflora of the respiratory organs, the alimentary canal and milk. Consideration of the number of species peculiar to each site shows the alimentary canal and milk to differ from other sites in the low percentage of exclusive species, 4·8 and 6·2 %, respectively, in contrast to a range of 11·8–27·6 % for other sites.

Table 5. *Number of species associated with six sites* and with mouldy hay, etc.*

	Site						
	Skin	Respiratory organs	Alimentary canal	Faeces	Reproductive organs	Milk	Hay, etc.
No. isolates	324	326	78	38	107	100	116
No. species	69	48	21	17	28	32	42
Percentage species at the one site only	27·6	16·6	4·8	11·8	21·4	6·2	17·4
Percentage species:							
Mycelial fungi (Phycomycetes and Fungi Imperfecti)	63·7	54·1	52·3	76·1	67·9	52·7	80·0
Yeasts	29·0	43·9	47·5	11·7	32·1	47·0	15·0

* On 9 animals (cattle, horse, sheep, pig, dog, cat, fowl, turkey, duck).

Pathogens and suspected pathogens

It is against the background sketched in the preceding section that the fungi recorded as pathogenic must be considered. No facilities were available for making pathogenicity tests, and consequently the evidence for the pathogenic involvement of any isolate was almost always circumstantial. For the dermatophytes and a few other well-established pathogens, identification was taken as evidence of pathogenicity. Other fungi were considered as pathogens only when isolated from sites at which they were observed by direct microscopical examination or when the clinical or laboratory evidence for their implication was very strong. Every case was considered both as fully as the case history allowed and in the light of the known habits of the species isolated. Any isolate of doubtful status was excluded and it is believed that the twenty-eight species of fungi and the single alga species listed below were primarily or secondarily pathogenic in at least 294 cases.

The name of each species, and any important synonyms, is followed by a reference to a description in a standard text and, whenever possible, to an illustration. Next the associated pathological conditions or the sites of isolation are listed, followed by the species of animal involved. The numbers in parentheses after each animal indicate the number of cases. Notes are added on the conditions associated with each species and also on the range of variation among the isolates.

An asterisk (*) indicates a new British host record.

1. **Absidia corymbifera** (Cohn) Saccardo. (Syn. *A. lichtheimii* (Lucet & Costantin) Lendner.) (Zycha, 1935, p. 127, fig. 58.)

Causing mucormycosis in guinea-pigs* (1). Associated with mycotic abortion in cattle (3). Isolated from a hen affected by a systemic disease (1).

2. **Absidia ramosa** (Lindt) Lendner. (Zycha, 1935, p. 134.)

Causing mucormycosis in guinea-pigs* (1). Associated with mycotic abortion in cattle (8). Isolated from the brain of a calf (1).

Direct evidence of pathogenicity of these two species was obtained from the outbreaks of mucormycosis in guinea-pigs when isolates were made from the internal organs of the affected animals. Of thirty-one cultures from this condition, nineteen were *A. ramosa* and twelve *A. corymbifera*, whilst a further isolate of each species was obtained from the associated samples of mouldy hay. From this it appears that both species were equally pathogenic and were isolated in a similar proportion to that found in the Survey as a whole.

The frequent appearance of these two fungi in association with animals does not seem to have been generally recognized, although their pathogenicity was accepted. Their isolation from other substrates, e.g. soil and plant debris, has rarely been reported and their natural habitat remains in doubt. It is possible that the association with animals is rather more than a coincidence and that the relationship requires further study.

3. **Haplosporangium parvum** Emmons & Ashburn. (Carmichael, 1951, pp. 609–611, figs. 1–3.)

Causing haplosporangiosis in moles* (1).

The occurrence of this fungus has already been recorded (McDiarmid & Austwick, 1954), together with a note on the mycology of the isolates. This is the first British record of the species, which is well known in parts of Canada and the U.S.A. from small mammals. The simultaneous occurrence of a nematode and a species of *Nocardia* in the lungs of the affected moles complicates the status of the fungus, as does its occurrence in twenty-five out of thirty-one apparently healthy moles. It seems probable, however, that a heavy infection may weaken an individual and perhaps contribute to the unexplained periodic fluctuations in mole mortality. Isolation of *H. parvum* was effected by dissecting the spherules from lungs, washing them in several changes of sterile water, plating on to nutrient agar (supplemented by antibiotics) and incubating at 25° C.

4. **Mucor pusillus** Lindt. (Zycha, 1935, p. 51, fig. 11.)

Associated with mastitis in cattle (1). Isolated from the brain and other organs of a calf* (1).

The pathogenicity of this species to man and animals is still open to doubt but the Survey records show that it is occasionally associated with disease in animals. The isolates all grew well at 37° C. and died out when maintained at 25° C. Two isolates were also made from bovine female reproductive tracts in unexplained cases of infertility. In two other isolates zygospores were present in abundance, although they do not appear to have been previously reported in this species.

5. **Mucor racemosus** Fres. (Zycha, 1935, p. 60, fig. 17.)

Associated with mastitis in cattle (2). Isolated from lungs of a rabbit (1) and a mink (1).

Although the dominant organism isolated from the rabbit and mink lungs in these two cases, and also the suspected cause of mastitis, this species is only doubtfully pathogenic, more especially as it must be regarded as a common member of animal mycofloras. Further isolates were obtained from the alimentary canal and lungs of poultry, and from hay and from bovine faeces.

A number of morphological variants were observed among the twenty-one isolates, mostly differing in the number of chlamydospores present, the denseness of growth and the different proportions of the various spore sizes found. None of this variation appeared to be related to suspected pathogenicity.

6. **Claviceps purpurea** Tul. (Butler & Jones, *Plant Pathology*, p. 445, figs. 221–223, 1949.)

Sclerotia of *C. purpurea* were found in one of two samples of hay fed to cows showing symptoms of ergot poisoning.

7. **Microsporum canis** Bodin. (Syn. *M. felineum* Mewborn, *M. lanosum* Sab.) (Conant, 1937, p. 12, pls. 2–4.)

Causing ringworm in the cat (17) and the dog (6).

Only one of the twenty-three isolates of this species was of the 'dysgonic' type, the remainder varying only slightly in the amount of aerial mycelium and pigment produced. One isolate at first failed to form the charactersitic yellow pigment but developed it in subcultures.

8. **Microsporum equinum** (Delac. & Bodin) Guéguen. (Conant, 1937, p. 13, pls. 2, 3 and 5.)

Causing ringworm in the horse (1).

Since the Survey was concluded two further isolates of *M. equinum* have been made, indicating that it is by no means rare.

9. **Trichophyton equinum** Gedoelst. (Sabouraud, *Les Teignes*, p. 388, figs. 175–9, pl. 23, 1910.)

Causing ringworm in the horse (5).

These five cases represented three separate outbreaks of equine ringworm. The source of the infection in two of the outbreaks was traced to horses bought at a sale. In each stable, the spread of the infection was rapid and involved a large number of animals.

The isolates were morphologically alike. The species is classified by Conant *et al.* (1954) as a variant of *T. mentagrophytes*.

10. **Trichophyton mentagrophytes** (Robin) Blanchard. (Syn. *T. gypseum* Bodin, *T. asteroides* Sab.) (Conant *et al.* 1954, p. 334, figs. 165, 166A, B.)

Causing ringworm in the cat (2) and the dog (6).

Considerable variation was noted both in the clinical symptoms observed and in the morphology of the isolates. One isolate had produced a copious cream-coloured mass of arthrospores between the claws of a cat and in culture gave a profusion of microconidia. The other cases exhibited either generalized lesions, resembling some *Microsporum canis* infections (3) or a favus-like condition of the head (3). Isolation failed in one of the canine samples but the absence of fluorescence under Wood's light and the presence of chains of arthrospores suggested that this species was involved.

Five of the isolates were of the 'asteroides' type and varied slightly in the colour and the amount of pigment produced. The remaining two corresponded to Sabouraud's 'niveum' group.

11. **Trichophyton verrucosum** Bodin var. **discoides** (Sab.) Georg. (Syn. *T. discoides* Sab.) (Sabouraud, *Les Teignes*, p. 408, figs. 183–7, pl. 24, 1910.)

Causing ringworm in cattle (41) and the horse* (1).

All culturally confirmed cases of cattle ringworm yielded this species. In seven microscopically positive cases isolation attempts were unsuccessful, apparently because the fungus had been killed by the application of fungicides to the lesions.

The single isolate from the horse is believed to be a new British host record. The horse had been grazing with heavily infected cattle and the dermatophyte, although not diagnosed microscopically, was isolated in quantity by a dilution technique.

The morphological differences between the isolates were chiefly variations in the relative abundance of the chlamydospores and microconidia, none of which appeared to be related to clinical differences, e.g. in response to treatment.

12. **Aspergillus flavus** Link. (Thom & Raper, 1945, p. 263, fig. 72.)

Causing aspergillosis in a tumbler pigeon (1) and in a turkey (1).

None of the slight variations encountered among the five isolates from all sources was apparently related to the pathogenic status. One isolate produced abundant sclerotia.

13. **Aspergillus fumigatus** Fres. (Thom & Raper, 1945, p. 148, fig. 37.)

Causing aspergillosis in birds (fowl, 60; turkey, 19; ducks, 7; geese, 5; parrot, 3; budgerigar, 1; Mandarin duck, 1; Abyssinian blue-winged goose, 1; Andean goose, 1; rook*, 1; jackdaw*, 1; wood-pigeon*, 4) and guinea-pig* (1); egg infections (duck, 1; goose, 1). Associated with mycotic abortion in cattle (32) and sheep (1); mastitis in cattle (8); and lung disorders in cattle (4) and pigs (4).

Very little variation in the appearance of the cultures was seen on standard media in the 219 isolates examined, but two strains of the extreme floccose type occurred and the colour of the reverse of the colonies was also variable. The appearance of this species when received on unsuitable media after incubation at 37° C. was often very abnormal. On meat or liver extract agar, growth was typical except that the colour rapidly changed to mauve. Other conditions of growth gave rise to sterile, floccose masses, which always produced typical colonies when subcultured on to malt agar.

A. fumigatus was the only filamentous fungus which was found within the bodies of animals in a freely sporulating state. Conidiophores were observed in five cases of advanced aspergillosis in birds in which the lumina of the tracheae, the bronchi and the air-sacs were completely lined with a greenish felt of sporing heads, overlying the mucosae. In one wood-pigeon the hyphae had spread from the lungs and formed conidiophores on the ventral surface of the pleura.

Aspergillus fumigatus was the only fungus isolated from approximately 60 % of the cases of avian aspergillosis. The associated fungi were chiefly *A. terreus*, *A. nidulans*, *Absidia ramosa*, *Mucor racemosus* and *Candida albicans*. In a series of isolations from clinically normal lungs from poultry which had died from causes other than aspergillosis, *Aspergillus fumigatus* figured frequently, together with species of *Penicillium* (each in 11 out of 25 cases). This may indicate that *A. fumigatus* may be present in poultry lungs without producing the characteristic symptoms of aspergillosis.

In spite of its prevalence as a pathogen, *A. fumigatus* was rarely isolated from feeding stuffs, etc. It was, however, commonly found in cultures from skin scrapings and hair samples, especially from cattle, and there is no doubt that it is one of the fungi characteristically associated with animals.

14. **Aspergillus nidulans** (Eidam) Winter. (Thom & Raper, 1945, p. 146, figs. 39, 40, 41.)

Causing aspergillosis in the fowl (chicks) (1). Associated with mycotic abortion in cattle (4); mastitis in cattle (1).

The twenty-three isolates of this species showed slight variation in the production of perithecia, but this did not appear to be connected with the pathogenicity of the isolates.

15. **Aspergillus niger** van Tieghem. (Thom & Raper, 1945, p. 216, figs. 61, 62.)

Causing aspergillosis in the fowl (2). Associated with mastitis in cattle (1).

In both the cases in fowls, the viscera were extensively involved and there are indications that this fungus, although rarely implicated as a pathogen, may be associated with a form of aspergillosis clinically different from that caused by *A. fumigatus*.

All the isolates agreed with *A. niger* van Tieghem sensu Thom & Raper. One nigger-brown variant was found.

16. **Aspergillus terreus** Thom. (Thom & Raper, 1945, p. 195, figs. 56, 57.)

Causing aspergillosis in a parrot* (1). Associated with mycotic abortion in cattle (6); mastitis in cattle (5).

The forty isolates were remarkably constant in characters. A few showed slight floccose growth.

17. **Graphium** V. 123.

Associated with abortion in cattle (2); mastitis in cattle (1).

No *Graphium* species appears to have previously been recorded from animal sources. The two abortions occurred in the same area and the fungus was the only isolate obtained directly from the hyphae observed in the stomach content of one of the foetuses. Isolations were also made from the lungs of this foetus. The mastitis isolate came from a cow producing abnormal milk.

18. **Candida albicans** (Robin) Berkhout. (Lodder & van Rij, 1952, p. 466, figs. 170–2.)

Causing moniliasis in birds (fowl, 11; turkey, 12; pigeon (squab)*, 1). Associated with vent gleet in ducks (1); with intestinal inflammation in a cow and a 6-month-old Boxer dog; with mastitis in cattle (1). Isolated from sternal lesions in a parrot* (1).

The forty-three isolates were all from the alimentary canal or from the respiratory organs, but only those made from actual lesions have been considered as pathogenic. Most of the remaining isolates were from poultry lungs and their status is unknown.

Chlamydospores were observed in all but eight of the isolates and a further eight produced gas in galactose fermentations. The remaining morphological and biochemical characters were quite constant.

19. **Candida krusei** (Cast.) Berkhout. (Lodder & van Rij, 1952, p. 492, figs. 178, 170.)

Associated with moniliasis in a turkey (1) and with mastitis in cattle (7).

This species is not accepted as a pathogen of man, but the circumstantial evidence in which eight of the isolates were made was sufficiently strong to suggest pathogenic behaviour in animals and the need for further study. The moniliasis case may have been one of vitamin A deficiency, but six of the seven mastitis isolates were the only organisms obtained from the milk samples concerned, and three of them were from penicillin-resistant cases. The remaining isolates from respiratory organs and skin were undoubtedly saprophytic. Some variation in the colour and degree of folding of the colonies was noticed.

20. **Candida tropicalis** (Cast.) Berkhout. (Lodder & van Rij, 1952, p. 502, figs. 182, 183.)

Associated with mastitis in cattle (2).

In both these cases the fungus was the only organism isolated.

21. **Cryptococcus neoformans** (Sanfelice) Vuillemin. (Lodder & van Rij, 1952, p. 373, fig. 131.)

Associated with uterine inflammation (metritis) in a cow* (1).

This isolate appeared to be pathogenically involved, but insufficient data were available to claim the disease with certainty as uterine cryptococcosis.

22. **Geotrichum candidum** Link. (G. Smith, *Introduction to industrial mycology*, ed. 4, p. 114, fig. 59, 1954.)

Associated with mycotic abortion in cattle (2); mastitis in cattle (3). Isolated from piglet stomach (1); faeces of piglet with scour (1); a dog with mucoid faeces (1).

Only seven of the nineteen isolates of this species came from pathological conditions to which they might have contributed as causal agents. The fungus is well known from milk (as *Oidium lactis*), and in the three mastitis cases it was the only organism obtained. Although also known as an inhabitant of the intestines of animals, its appearance in quantity in the two faeces samples may have indicated a disorder favouring its rapid growth.

Other isolates were obtained from skin scrapings and also from the lungs of poultry, where they were not associated with any clinical symptoms.

Three different colony types occurred amongst the isolates, a slimy yeast-like growth (two isolates), a dry flat growth (7); and a dry floccose growth (4). All these came within the limits of the species as defined by Colonello (1944). The remaining isolates were not grouped.

23. **Pityrosporum pachydermatis** Weidman. (Lodder & van Rij, 1952, p. 443.)

Associated with ulceration of the conjunctiva of a dog* (1).

This organism grew on malt agar without added oleic acid. The dog affected was also suffering from paronychia and ulceration of the ear tips, nasal mucosa and prepuce. Similar isolates from dogs' ears have been reported from Sweden (Miss A. v.d. Hoven van Genderen, *in litt.*).

24. **Trichosporon cutaneum** (de Baum., Gougerot & Vaucher) Ota. (Lodder & van Rij, 1952, p. 619, fig. 246.)

Isolated from the throat of a dog* (1).

This dog showed symptoms of tuberculosis, but no acid-fast bacteria could be detected. Three of the five isolates showed the mucoid form of colony and the other two were matt and folded.

25. **Torulopsis** V. 250.

Associated with moniliasis in a turkey (1).

This yeast has been isolated on six occasions from the respiratory organs and crops of poultry, but only once as a suspected pathogen. Previous to the Survey a number of similar isolates had been received from cases of moniliasis in poultry.

According to Miss A. v.d. Hoven van Genderen, of the Centraalbureau voor Schimmelcultures, Delft, these isolates are related to *T. glabrata*, but differ in their larger cells and more exacting vitamin requirements.

25*a*. **T. glabrata** (Anderson) Lodder & de Vries (Lodder & van Rij, 1952, p. 407, fig. 142) was isolated from a chick lung which had pin-point lesions. No other organism was recovered but the isolate was of uncertain status.

Actinomycetes

The frequent isolation of Actinomycetes, especially aerobic forms, from both the skin and the internal organs of animals was one of the most interesting features of the Survey. Of the fifty-two isolates of Actinomycetes, one was *Actinomyces bovis*, two were classified in *Nocardia* and the remaining forty-nine in *Streptomyces*, following Waksman and Henrici (in Bergey, 1948). The circumstances of isolation pointed to suspected pathogenicity on twenty-seven occasions. The specific identities of all but *Actinomyces bovis* remain unknown.

26. **Actinomyces bovis** Harz.

Isolated from a large central abscess in the ventricles of the brain of a 3-week-old Shorthorn heifer calf and kindly identified by Dr Dagny Oxford.

27. **Nocardia** spp.

Isolated from the lungs of moles (1) and a piglet (1).

The mole isolate was pathogenic to laboratory mice and occurred in association with *Haplosporangium parvum*. The one from the piglet was found as a single colony amongst a heavy growth of a species of *Streptomyces* and was probably of no pathogenic significance.

28. **Streptomyces** spp.

Isolated from the lungs of cattle (11); pigs (10); sheep (1); dog (1); partridge (1); and from other organs of cattle (4). Associated with mastitis in cattle (5).

The majority of the lung isolates were obtained during the winter months from young animals showing a variety of symptoms, usually respiratory, or of general weakness, and death had often taken place within a few days of their appearance. On thirteen occasions the *Streptomyces* sp. was the only organism isolated, often in profusion, whilst fungi associated with the other isolates included *Aspergillus fumigatus*, *A. terreus*, *Absidia corymbifera*, *A. ramosa* and *Mucor pusillus*.

The pathogenicity of the isolates has not been investigated, and it is possible that they are purely saprophytic, and occur in normal lungs.

However, their abundance on primary isolation plates indicates that large numbers of the organisms must have been present in many of the affected organs.

By far the greatest number of isolates from all sources (43) were of the chalky-white, heavily sporing non-pigmented type, included in the *Streptomyces albus* group, whilst the remaining six produced orange or pink colonies and belonged to other series. A fuller investigation of the identity and pathogenicity of these isolates is needed before any assessment can be made of their importance as pathogens.

Prototheca portoricensis Cif., Ashf. & Dalmau. (Ashford, Ciferri & Dalmau, 1930, *Archiv Protistenkunde*, 70, 619–636, fig. 1.)

Associated with mastitis in cattle* (1).

Although a colourless member of the Chlorophyceae, this organism has been included here because it may be pathogenic, and has not previously been reported in this country.

Host index

Mammals	Species number
Cat	(*Felis catus*) 7, 10
Cattle	(*Bos taurus*) 1, 2, 4, 5, 6, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 26, 28
Dog	(*Canis familiaris*) 7, 10, 18, 22, 23, 24, 28
Goat	(*Capra hircus*) indet. sp.
Guinea-pig	(*Cavia porcellus*) 1, 2, 13
Horse	(*Equus caballus*) 8, 9, 11
Mink	(*Mustela vison*) 5
Mole	(*Talpa europaea*) 3, 27
Pig	(*Sus domestica*) 13, 22, 27, 28
Rabbit	(*Oryctolagus cuniculus*) 5
Sheep	(*Ovis aries*) 13, 28
Birds	
Budgerigar	(*Melopsittacus undulatus*) 13
Duck, Domestic	(*Anas platyrhynca*) 13, 18
Duck, Mandarin	(*Aix galericulata*) 13
Fowl	(*Gallus domesticus*) 1, 13, 14, 15, 18, 25*a*
Goose, Abyssinian Blue-winged	(*Cyanochen cyanopterus*) 13
Goose, Andean	(*Chloephaga melanoptera*) 13
Goose, Domestic	(*Anser cineratus*) 13
Jackdaw	(*Corvus monedula*) 13
Parrot	(*Psittacus*) 13, 16, 18
Partridge	(*Perdix perdix*) 28
Pigeon, Domestic	(*Columba livia*) 12, 18
Pigeon, Wood	(*Columba palumbus*) 13
Rook	(*Corvus frugilegus*) 13
Turkey	(*Meleagris gallopavo*) 12, 13, 18, 19, 25

DISCUSSION AND CONCLUSIONS

The Survey was primarily exploratory. It had, as already implied, a mycological bias and the terms of reference were 'a survey of the fungi associated with disease in farm animals'. What conclusions may be drawn from the results?

Perhaps the most interesting mycological aspect of the results is the long list of fungi isolated from the morbid material. Most of these fungi are undoubtedly derived from the environment, for the air of farm buildings, for example, is well known to have a very much greater concentration of fungus spores than outdoor air. While the results do not suggest that the different animals have characteristic mycofloras they indicate that certain moulds are frequently associated with animals, and the explanation of this association appears to merit further investigation. During recent years evidence has accumulated that fungi are only incidentally pathogenic for animals and that most of the fungi pathogenic for man and animals are normally saprophytes in diverse habitats and particularly in the soil. Of the twenty-eight species recorded as pathogenic, seven (the five dermatophytes, *Haplosporangium parvum*, and *Cryptococcus neoformans*) can be classified from the point of view of the Survey, as 'obligate' pathogens, for their isolation was taken as prima facie evidence that they were causally involved in the condition. None of these species was recorded during the Survey as a saprophyte. Of the remaining twenty-one species, eleven (52·3 %) were recorded from mouldy hay and for all species the percentage recorded for this material was 36·4. It would thus appear that mouldy feedingstuffs are possibly an important source of pathogenic fungi.

Apart from mucormycosis in guinea-pigs (caused by *Absidia corymbifera* and *A. ramosa*), which is apparently undescribed, and haplosporangiosis (*Haplosporangium parvum*) in moles, which is both a new host record for this prevalent mycosis of North America and the first European record for the condition, no new major mycosis was discovered and none of the important mycoses of domesticated animals endemic in other parts of the world and unknown here was recorded. (By analogy with mycotic infection of man, however, it would appear to be not unlikely that histoplasmosis (*Histoplasma capsulatum*), if not other mycoses, occasionally attacks dogs and perhaps other animals in this country.) The results of the Survey indicate clearly that while the number of different mycoses affecting animals in Britain is relatively small, there are several, e.g. aspergillosis, ringworm, and moniliasis, which are of considerable economic importance. The results also indicate that fungi may be involved in the etiology of certain conditions, such as bovine mastitis and abortion, which have not hitherto been considered to be of mycotic origin. Further, they emphasize the lack of accurate information on the distribution and epidemiology of even the commoner mycoses of animals in Britain. It is clear that the role of fungi in animal disease has not been fully appreciated and that there is a great need for further investigations into the relationships between fungi and animals.

Grateful acknowledgements are made to the Agricultural Research Council for sponsoring the Survey and to the Veterinary Investigation Service and the numerous correspondents whose co-operation made the Survey possible. Thanks are also due to Dr A. H. S. Brown, Dr C. G. Dobbs, Dr W. P. K. Findlay, Dr W. L. Gordon, and Mr George Smith, and to the Commonwealth Mycological Institute, Kew, and the Centraalbureau voor Schimmelcultures, Delft and Baarn, for identifying isolates. We are also indebted to Miss P. M. Stockdale and to Miss J. Edmundson for laboratory help and to Mrs J. Steed for technical assistance.

REFERENCES

Ainsworth, G. C. & Austwick, P. K. C. (1955). A survey of animal mycoses in Britain: general aspects. *Vet. Rec.* **67**, 88–97.

Austwick, P. K. C. (1954). The isolation of *Trichophyton discoides* from cattle. *Vet. Rec.* **66**, 224–225.

Carmichael, J. W. (1951). The pulmonary fungus *Haplosporangium parvum*. II. Strain and generic relationships. *Mycologia*, **43**, 605–624.

Colonello, F. (1944). Il *Geotrichum candidum* quale ospite dell'organismo umano. *Atti Ist. bot. Univ. Pavia*, ser. 5, **3**, 197–224.

Conant, N. F. (1937). Studies in the genus *Microsporum*. III. Taxonomic studies. *Arch. Derm. Syph., Chicago*, **36**, 781–808.

Conant, N. F., Martin, D. S., Smith, D. T., Baker, R. D. & Callaway, J. L. (1954). *Manual of clinical mycology*, ed. 2, pp. 456. Philadelphia.

Eastwood, D. J. (1952). The fungus flora of composts. *Trans. Brit. mycol. Soc.* **35**, 215–220.

Hoerlein, A. B. (1945). Studies on animal dermatomycosis. *Cornell Vet.* **35**, 287–307.

Kligman, A. M. & Mescon, H. (1950). The period acid-Schiff stain for the demonstration of fungi in animal tissue. *J. Bact.* **60**, 415–421.

Littman, M. L. (1947). A culture medium for the primary isolation of fungi. *Science*, **106**, 109–111.

Lodder, J. & van Rij, N. W. J. Kreger (1952). *The yeasts. A taxonomic study*, pp. 713. Amsterdam.

McDiarmid, A. & Austwick, P. K. C. (1954). Occurrence of *Haplosporangium parvum* in the lungs of the mole (*Talpa europaea*). *Nature, Lond.*, **174**, 843–844.

Raper, K. B. & Thom, C. (1949). *A manual of the Penicillia*, pp. 875. London.

Thom, C. & Raper, K. B. (1945). *Manual of the Aspergilli*, pp. 373. Baltimore.

Waksman, S. A. & Henrici, A. T. (1948) in *Bergey's Manual of Determinative Bacteriology*, pp. 892–980.

Warcup, J. H. (1951). The ecology of soil fungi. *Trans. Brit. mycol. Soc.* **34**, 376–399.

Zycha, H. (1935). Mucorineae in *Kryptogamenflora der Mark Brandenburg*, **6a**, Pilze II. Leipzig.

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Trans. Brit. mycol. Soc. **38** (4), 387–399 (1955).

NEW OR INTERESTING RECORDS OF BRITISH HYMENOMYCETES

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(With 14 Text-figures)

Descriptions are given of fifteen Hymenomycetes, twelve of which belong to the Agaricaceae, and one each to the Boletaceae, Thelephoraceae and Clavariaceae. Eleven Agarics and one Bolete are recorded as additional to Pearson & Dennis's 'Revised List of British Agarics and Boleti', and two, *Mycena mackinawensis* A. H. Smith and *Lepiota pseudogranulosa* (Berk. et Br.) Sacc. sensu Dennis, as new to Europe.

During the past few years a number of interesting Hymenomycetes have been collected or received by the author, some of which are additions to the British Fungus Flora, whilst others are rare or little-known species. It was therefore decided to publish a short account of these in the hope that it may prove useful to others interested in this group of fungi. The collections cited are deposited in the Kew Herbarium, unless otherwise stated.

Lepiota setulosa Lange, in *Fl. Agar. Dan.* **1**, 34, 1935

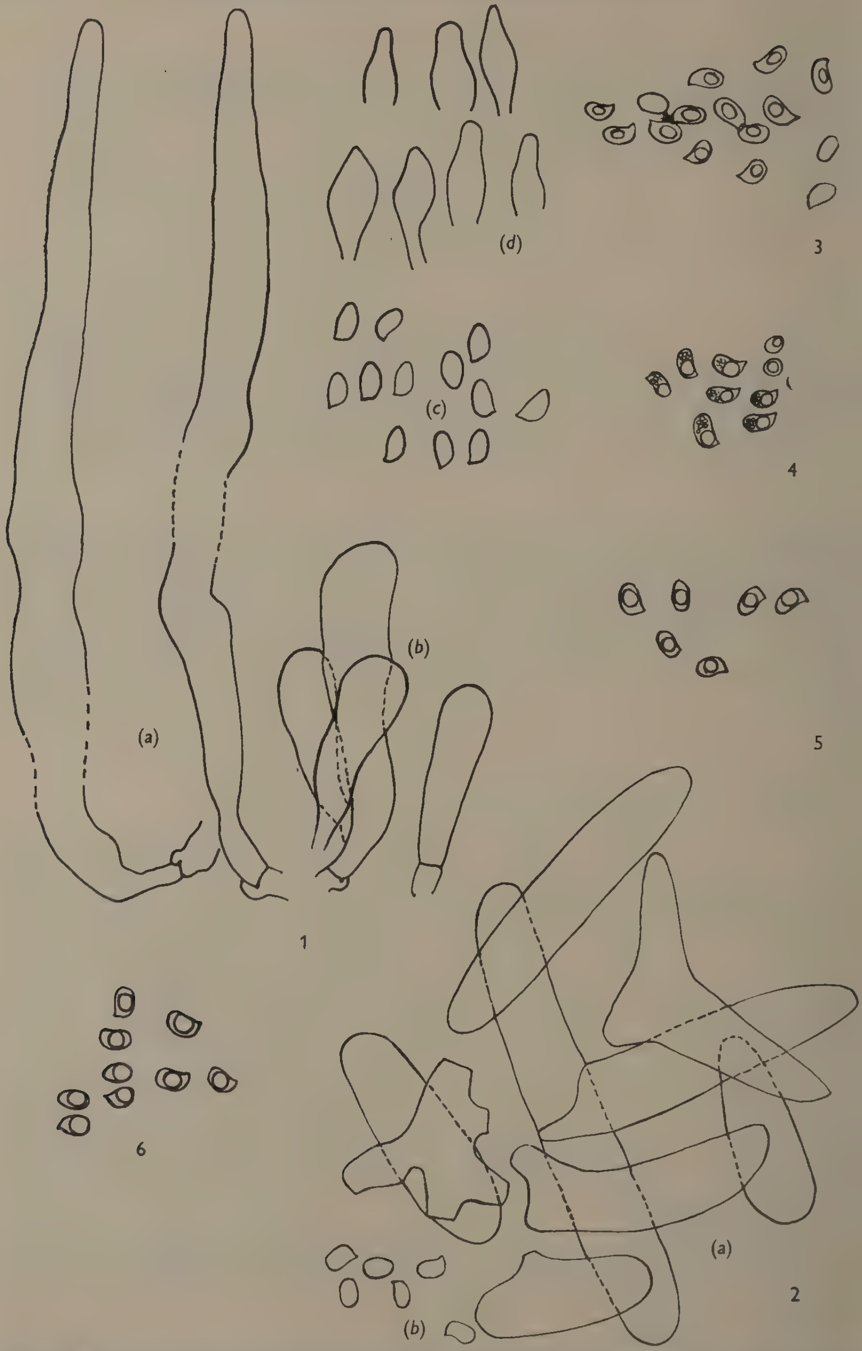
Synonym: *L. minuta* Lange, in *Dansk bot. Ark.* **4**, 48–49, 1923.

Cap 1–1·5 cm., convex then nearly flat with obtuse central umbo, reddish brown, paler at margin, covered with conical pilose squamules, soon breaking up into minute brown granules on white background, except at disk. *Gills* moderately crowded, ventricose, unequal, free, white, with crenulate edge. *Stem* 3 cm. high, 0·15 cm. diam., whitish, with few scattered brown floccules toward the base. *Ring* absent, but remnants of cortina form brown annular zone. *Spores* hyaline, elliptical, 5–7 × 3–4 μ. *Gill edge* with cystidia of variable shape, 23 × 5–10 μ mostly fusoid, but others ventricose to almost cylindrical, many with short obtuse necks. *Cap surface* of narrow, branched, brown hyphae, with clamp connexions, from which arise numerous, brown, thin-walled aseptate hairs, up to 265 μ long, 13 μ wide, with narrowed obtuse apices, together with much shorter, almost hyaline, clavate cells, which form a rather indistinct hymeniform layer at base of hairs.

Habitat under hazel in mixed wood, Burnham Beeches, Bucks., 4 October 1953; in hedgerow under hazel, beside road from Doverhay to Horner (Porlock), Somerset, 24 August 1954.

(Section: *Ovisporae.*)

L. setulosa is very closely related to *L. rhodorrhiza* (Romagn. et Locq.) Kühn. et Romagn., which was originally described as a variety of this



Figs. 1–6. Fig. 1. *Lepiota setulosa*: (*a*) hairs on cap surface; (*b*) cells forming hymeniform layer at base of hairs; (*c*) spores; (*d*) cheilocystidia. Fig. 2. *L. pseudogranulosa*: (*a*) cells of mealy covering to cap; (*b*) spores. Fig. 3. *Tricholoma inocybeoides*: spores. Fig. 4. *T. cingulatum*: spores. Fig. 5. *T. populinum*: spores. Fig. 6. *T. spinulosum*: spores. All ×866.

fungus, but is easily distinguished from it as the stipe lacks the characteristic basal rose-coloured rhizoids and is not easily separable from the cap. *L. subincarnata* Lange is another closely allied species differing in its more robust stature, rosy coloration, clavate cystidia, and lack of an hymeniform layer at the base of the hairs on the cap surface. *L. rhodorrhiza* and *L. subincarnata* have yet to be found in Britain.

Lepiota pseudogranulosa (Berk. et Br.) Sacc. sensu Dennis, in *Kew Bull.* p. 486, 1952

Cap 2 cm., semiglobate or campanulate, covered with thick white meal, tinted pink or reddish brown in places, especially where handled. *Gills* subdistant, ventricose, unequal, free, white. *Stem* 2·5 cm. long, 0·2 cm. diam., equal, hollow, white, with white mealy covering beneath ring. *Ring* superior, white, mealy below. *Spores* elliptical 3·5–4 × 2·5 μ, hyaline, non-amyloid. *Gill edge* with thin-walled, cylindrical cystidia, 40 × 7 μ. *Cap surface* with mealy covering formed of elongated, hyaline, thin-walled, cylindrical or subcylindrical cells, 39–96·2 × 8–16 μ, which are often variously branched.

Habitat under manured shrubs, near Aroid House, Royal Botanic Gardens, Kew, Surrey, 8 November 1951.

(Section: *Micaceae.*)

This tropical species, originally described from Ceylon, was reported by Dennis from Venezuela, growing on soil and rotting logs in forests, but there seems to be no previous record of it occurring in Europe, either naturally or under glasshouse conditions. Despite the fact that the sporophore was growing naturally, it seems reasonable to assume that it must have been introduced with soil adhering to some tropical plant, especially in view of the close proximity to a heated glasshouse. Of the European species it is most closely related to *L. rufescens* B. & Br. (*L. rosea* Rea is said by Lange to be hardly specifically distinct from this species), and indeed cannot be distinguished from it by eye, although the globose cells forming the mealy covering of the cap in *L. rufescens* afford an easy means of separation.

Tricholoma inocybeoides Pearson, in *Trans. Brit. mycol. Soc.* **22**, 29, 1938

Synonym: *T. myomyces* (Pers. ex Fr.) Lange var. *albo-conicum* Lange, in *Fl. Agar. Dan.* **1**, 55, 1935.

Cap 2·5 cm., conical or campanulate then flat, with very prominent acute umbo, pale grey, covered with fine felt-like fibrils, later almost white, becoming glabrous, except for few, scattered, grey-brown fibrils round darker umbo. *Gills* moderately crowded, unequal, emarginate, whitish, turning bright yellow in places during decay, like rest of fungus. *Stem* 2·5 cm. long, 0·25 cm. diam., whitish, without trace of annular zone. *Spores* hyaline, elliptical, 4–6 × 2·5–3·5 μ, with central guttule. *Smell* not noticeable. *Taste* mild.

Habitat abundant under poplars, Royal Botanic Gardens, Kew, Surrey, October 1953.

(Section: *Myomyces.*)

Lange described this species from Denmark as a variety of *T. myomyces* (Pers. ex Fr.) Lange, but Kühner & Romagnesi (1953) regarded both names as synonyms of *T. scalpturatum* (Fr.) Bres. Pearson (1938) described *T. inocybeoides*, which seems to be hardly specifically distinct, differing only in having a strong smell—a feature which could have been the result of decay. In view of the small size, acute conical umbo, and pale coloration, it was decided to retain this as a distinct species. Pearson (1938) gave a very good description of it when he wrote: 'This plant looks strikingly like a small whitish *Inocybe* with a dark umbo.'

Tricholoma cingulatum (Almfelt) Jacobasch, in *Verh. bot. Ver. Brandenb.* **33**, 59, 1892

Cap 4–6 cm., convex, often indistinctly umbonate, varying from pale grey at first to greyish brown in old specimens; surface covered by adpressed felty fibrils; margin whitish, incurved, shaggy with remnants of veil. *Gills* moderately crowded, unequal, sinuate, pale greyish white, becoming bright yellow in places as fruit-body begins to decay. *Stem* up to 7 cm. long, 0·7 cm. diam., equal, pale greyish white. *Ring* narrow, cottony, situated toward apex of stem. *Spores* narrowly elliptical, $4–5 \times 2·5\,\mu$ with a number of small guttules.

Habitat abundant under small bushes of *Salix atrocinerea*, in disused sandpit, Leighton Buzzard, Beds., 14 October 1951; Juniper Hill, Mickleham, Surrey, coll. P. Orton, 6 October 1952.

(Section: *Myomyces*.)

It has been suggested by Lange (1935) that this fungus is always associated with Salices, and Fries (1874) himself stated that it grew under Salices. This association, although frequent, is not apparently constant, as Métrod (1939) records it under the name of *T. ramentaceum* (Bull. ex Fr.) Ricken growing in a wood of young *Picea*.

In the past the name *T. cingulatum* has been regarded by many mycologists as a synonym of *T. ramentaceum*, so that it is possible that some British collections have been so named. Berkeley, Cooke, Massee, and Rea each gave descriptions of *T.* (*Armillaria*) *ramentaceum* which could equally apply to *T. cingulatum*. It was therefore decided to re-examine the old gatherings of *T. ramentaceum* preserved in the Kew Herbarium, but unfortunately there are only three such collections. There is material named by Cooke, from W. Weir's pasture, Hampstead, 1863, which has large subglobose to oval spores (6) $7–8 \times 5–6\,\mu$, and two other collections from Coed Coch, 1866 and 1859, named by Berkeley, together with a painting, showing that one of these, at least, lacked a ring, and had dark floccose squamules on the stipe. It is thus clear that none of these three gatherings can be referred to *T. cingulatum*, and that Berkeley and Cooke lacked a clear conception of *T. ramentaceum*.

T. cingulatum differs from the description and plate (pl. 595) of *T. ramentaceum* given by Bulliard (1812) in its lack of free gills, black bristly squamules on the cap, and spreading membranous ring. It would therefore seem advisable to drop the name *T. ramentaceum*, in view of the confusion regarding its usage, and to retain the name *T. cingulatum* for that species of the

Myomyces section of the genus bearing a narrow cottony ring on the stem. This would have the advantage of bringing our nomenclature into line with that of modern continental mycologists.

This species was first reported from Britain by Reid (1952).

Tricholoma populinum Lange, in *Dansk bot. Ark.* **8**, 14–15, 1933

Cap 8–12 cm., convex, pale brown, tinged with flesh colour, becoming progressively darker with age, especially toward disk; surface frequently disrupting to form dark brown scales, often viscid near undulating margin. *Gills* moderately crowded, unequal, sinuate, white, rufescent with age. *Stem* up to 8 cm. long, 1·5 cm. in diam. at slightly swollen base, usually short and stout, pale at first, then more or less concolorous with cap, often densely covered with dark brown adpressed fibrils in lower region. *Spores* hyaline, broadly elliptical, $5{\cdot}5 \times 3{\cdot}5\,\mu$ with large central guttule. *Flesh* whitish. *Smell* strong, farinaceous.

Habitat abundant in short grass under poplars, forming large subcaespitose clusters, Royal Botanic Gardens, Kew, Surrey, October 1953. (Section: *Brunneola*; subsection: *Limacina.*)

This species is easily recognized from its large size, and habit of growing in subcaespitose clusters under poplars.

Tricholoma spinulosum Kühner et Romagnesi, in *Bull. mens. Soc. linn. Lyon*, pp. 134–137, 1947

Synonym: *T. guttatum* (Schaeff. ex Fr.) Sacc. sensu Lange, in *Fl. Agar. Dan.* **1**, 55, 1935.

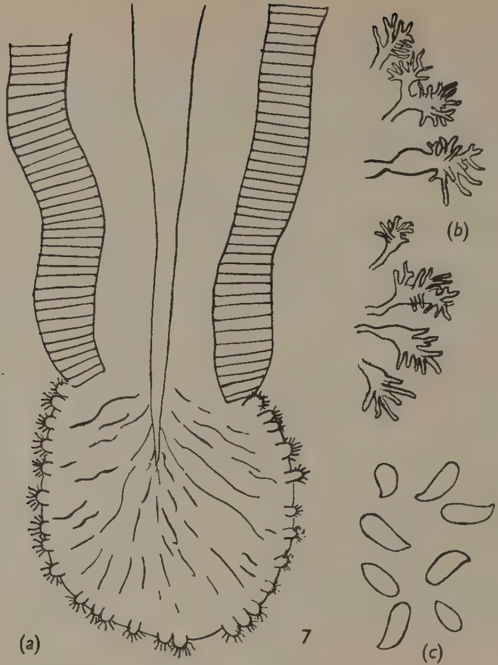
Cap 6·5 cm., convex, pale brownish fawn with darker streaks, disrupting to form adpressed squamules on whitish ground, in region of spinulose, enrolled margin. *Gills* moderately crowded, unequal, sinuate, cream. *Stem* 6 cm. long, 1·4 cm. diam., pale cream, becoming brownish near base. *Spores* hayaline, elliptical, amyloid $4\text{–}5 \times 3\,\mu$, with central guttule. *Flesh* white. *Smell* strong, very characteristic, of flowers (hyacinths or roses?), said by Romagnesi to be a little butyraceous at first then sweetly of stocks or orange flowers.

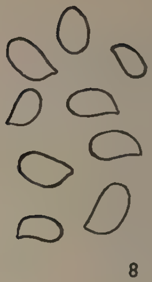
Habitat in short grass under *Forsythia*, Royal Botanic Gardens, Kew, Surrey, 25 September 1952.

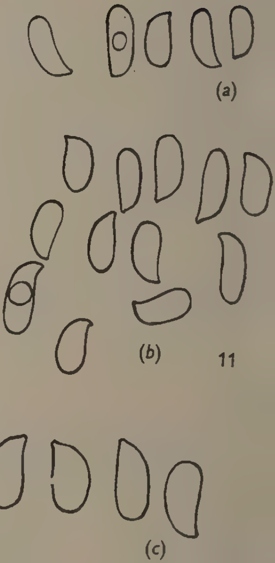
Pearson & Dennis (1948) list *T. orirubens* Quél. var. *guttatum* (Schaeff.) Pearson et Dennis, but this is a different species from that described above. The plate (pl. 76) of Cooke (1881–3), under the name *T. guttatus*, is likewise another fungus of *terreum-orirubens* affinity.

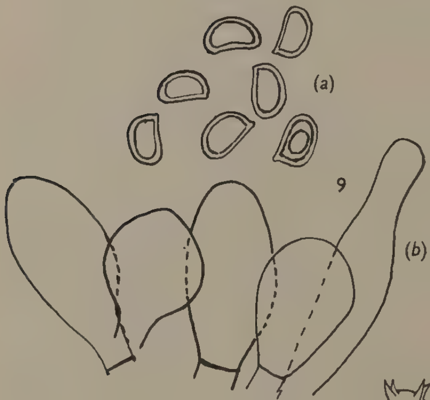
Mycena mackinawensis A. H. Smith, in *Pap. Mich. Acad. Sci.* **38**, 67–70, 1953

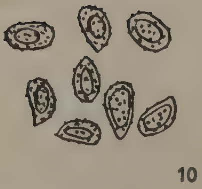
Cap up to 2 cm., convex to campanulate, strongly plicate to the distinctly depressed apical disk, dark sooty-grey, then somewhat olivaceous; surface viscid, with thick, separable, gelatinous pellicle. *Gills* distant, arcuate, somewhat decurrent, grey. *Stem* up to 8 cm. long, 0·2 cm. wide, viscid, concolorous with pileus. *Spores* hyaline, amyloid elliptical, $9\text{–}10 \times 3\text{–}3{\cdot}5\,\mu$.

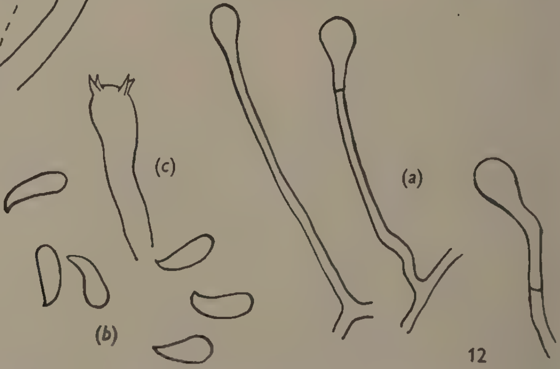












Figs. 7–12. Fig. 7. *Mycena mackinawensis*: (*a*) section through gill; (*b*) cheilocystidia; (*c*) spores. Fig. 8. *Hygrophorus chrysaspis*: spores. Fig. 9. *Flammula agardhii*: (*a*) spores; (*b*) cheilocystidia. Fig. 10. *Cortinarius urbicus*: spores. Fig. 11. *Clavaria ligula*: (*a*) spores of Berkeley's material from Strachan; (*b*) spores from Rothiemurchus material; (*c*) spores of *Clavaria pistillaris* for comparison. Fig. 12. *Cyphella lactea*: (*a*) hairs; (*b*) spores; (*c*) basidium. Fig. 7*a*, ×400; others, ×866.

Gill edge and *Subhymenium* strongly gelatinized. *Pleurocystidia* very rare, according to Smith they are '30–45 × 8–13 μ, essentially fusoid-ventricose and arising in the subhymenium, smooth or with one or more bumps or short projections, some branched at or near the apex, in most the ventricose portion above the mid-point and narrowed evenly to an obtuse or subacute apex, without an appreciable neck, hyaline thin-walled not staining in Melzer's solution'. *Cheilocystidia* very variable, mostly cylindrical or clavate, often branched, covered with finger-like processes.

Habitat on fallen coniferous branches, Windsor Great Park, Berks., coll. Miss P. Kertland and Miss J. Taylor, 25 October 1953.

(Section: *Glutinipedes*.)

Smith states that *M. mackinawensis* is known in the U.S.A. from the Douglas Lake region as well as from the Rifle River area of the Conservation Department at Lupton. The collection cited above is, however, the first record of its occurrence in Europe.

The species is closely related to *M. pelliculosa* (Fr.) Quél. sensu Smith, but differs from it in being confined to coniferous wood, and in having pleurocystidia of only one type (i.e. fusoid-ventricose) whilst the latter has, in addition, others resembling the cheilocystidia in that they are covered by finger-like processes.

The author wishes to express his thanks to Prof. A. H. Smith for his kindness in identifying specimens.

Hygrophorus chrysaspis Métrod, in *Rev. Mycol., Paris*, **3**, 153–156, 1938

Cap 3–6 cm., convex, then flattened, often indistinctly umbonate, very viscid in wet weather, pure white at first, becoming cream with ochraceous patches, finally entirely rusty-brown; cuticle frequently rupturing toward margin forming more or less distinct scales, exposing pale cream flesh. *Gills* thick, distant, unequal, decurrent, pale cream, more deeply coloured with age, turning almost black in dried specimens. *Stem* up to 6 cm. long, 1·2 cm. diam., base narrow pointed, apex floccose often exuding yellowish viscous droplets, cream, becoming stained with ochraceous patches, finally brown in lower portion. *Spores* hyaline, broadly elliptical, 8–9 × 4–5 μ. *Flesh* of cap, pale cream or whitish, but pale rusty-brown in stem. *Smell* strong, very similar to that of *H. eburneus*.

Habitat under beech, Aldbury, Herts., 5 September 1954.

(Section: *Limacium*; subsection: *Candidi*.)

It is not surprising to find that this species has, until recently, been completely overlooked in Britain, where it has almost certainly been passed over as sun-scorched *H. eburneus*. Apart from the blackening of the gills in drying, and the colour change of the cap from white to rusty-brown, which is best seen in specimens which have been kept for a day or more, it can readily be separated from *H. eburneus* by its reaction to strong bases (KOH, etc.) which rapidly produce a brown stain.

H. chrysaspis is probably common in this country in calcareous regions, and the following collections in the Kew Herbarium should be referred to this species: *H. cossus*, Cirencester Park, Glos., coll. E. M. Wakefield, 14 October 1936; *H. eburneus*, Loughton, 1879, Herb. M. C. Cooke.

Flammula agardhii (Lund apud Fr.) Karst., in *Hattsvampar*, p. 411, 1879

Cap 3–6 cm., convex becoming deeply depressed at centre, fibrillose, pale cinnamon-brown, darkening with age; surface often breaking up into irregular areolae. *Gills* moderately crowded, unequal, adnate with decurrent denticle, pallid clay coloured, then dark brown with olivaceous tinge. *Stem* up to 6 cm. long, 0·6 cm. diam., fibrillose, concolorous with cap, bearing well developed, more or less persistent cortina towards apex. *Spores* smooth, brown, ovate-phaseoliform, 9–10 × 4–5 μ. *Gill edge* with numerous globose or oval, thin-walled cystidia, 8–20 μ in diameter.

Habitat abundant under *Salix atrocinerea*, in disused sandpit, Leighton Buzzard, Beds., 9 September 1951.

(Section: *Subsiccae*.)

This species was first recorded from Britain by Reid (1952).

Cortinarius urbicus (Fr.) Fr., in *Epicrisis*, p. 293, 1838

Cap up to 6 cm., convex, whitish-clay, with lilac tinged, silky-arachnoid remnants of veil towards margin. *Gills* moderately crowded, unequal, rust-coloured, tinted purple in young specimens. *Stem* 4–8 cm. long, 1·0 cm. diam., whitish, with peronate covering, forming irregular ragged ring, above which is a zone of rusty fibrils formed by cortina. *Spores* brown, minutely punctate, elliptical, (5)–9 × 4–4·5 μ.

Habitat abundant under *Salix atrocinerea* and *S. viminalis*, growing in large clusters, in disused sandpit, Leighton Buzzard, Beds., 21 October 1951.

Cortinarius urbicus was previously recorded on a Woolhope Club foray to Cabalva in October 1879, but was excluded by Pearson & Dennis (1948) from the British list, pending confirmatory collections. No further report of its occurrence was published until Reid (1952) established its presence in Bedfordshire.

Inocybe hirtella Bres., in *Fung. Trid.* **1**, 52–53, 1884

Cap 1–3 cm., convex or campanulate, then flattened, with small obtuse, central umbo, pale yellow to ochre-brown; surface fibrillose, disrupting to form upturned scales in older specimens. *Gills* moderately crowded, unequal, clay-coloured. *Stem* 3 cm. long, 0·25 cm. diam., with subterranean bulb, whitish except for rosy tint toward apex. *Spores* smooth, brown, variable, 8–11 × 5–7 μ. *Cheilocystidia* variable, thick-walled, encrusted, broadly ovoid, elongated with short obtuse necks and ventricose bases, or almost cylindrical, up to 52 μ long, 18 μ wide. (Heim (1931) state sthat they are up to 78 μ long in adult sporophores.) *Paracystidia* on gill edge, thin-walled, ovoid or pyriform. *Pleurocystidia* similar to those on gill edge. *Caulocystidia* present over whole stem surface, shape variable, according to position; those at apex very like cheilocystidia; those farther down becoming broader and thinner-walled; those at base almost all thin-walled, and very broadly ovoid. *Smell* often faint, but characteristic, of bitter almonds (best observed on young specimens kept in closed container), slightly spermatic when old.

Habitat under hazel, Whippendell Woods, Croxley Green, Herts., coll. P. H. Gregory, 16 October 1954.

(Section: *Levisporae*; subsection: *Muriculatae*.)

This species was said by Heim (1931) to occur in England, but there seems to be no published British record.

Coprinus martinii Favre, in *Bull. Soc. mycol. Fr.* **53**, 286–290, 1937

Cap up to 2 cm. high, 0·8 cm. wide, cylindrical, becoming campanulate, then more or less flattened, with central umbo, delicate, pulverulent, ashy grey; margin grooved, finally revolute. *Gills* crowded, free, grey at first, then black. *Stem* up to 6 cm. long, 0·5 cm. diam., narrowing to 0·2 cm. at apex, hyaline, glabrous, except for villose base. *Spores* dark-brown, elliptical, $12–16 \times 7–8\mu$, with large apical germ pore; 'sac périsporique' present, as stated by Kühner in Kühner & Romagnesi (1953). *Cheilocystidia* and *Pleurocystidia* normally abundant, but evidently collapsing as gills deliquesce, for no trace could be found of these structures in specimens 2 days after collection. According to Favre, they are 'ovales-allongées ou subfusiformes, très grandes, jusqu'à 115μ'. *Cap surface* powdery with globose to ovoid cells, $26–52\mu$ wide, which are covered with numerous, minute, projecting granules.

Habitat on *Scirpus caespitosus* (?), Sheffield, Yorks., 9 October 1954.

(Section: *Farinosi*; subsection: *Exannulati*.)

The first British record of this fungus was that by Dennis (1948) from Shieldaig, Wester Ross, on *Scirpus caespitosus*, 2 June 1947, but there is also a collection in the Kew Herbarium made by Dennis from Parish Marsh, Wheatfen, Norfolk, on *Juncus subnodulosus*, 26 May 1947.

Boletus discolor (Quél.) Gilbert, in *Les Bolets*, p. 172, 1931

Cap 6 cm., strongly convex, brilliant sulphur yellow, bruising indigo blue, then black, on handling, as does stipe. *Pores* small, free, orange, passing to pale yellow beneath cap margin. *Stem* 12 cm. long, 1·3 cm. in diam. at apex, expanding slightly toward fusoid base, bright yellow, densely covered except for apex with minute, red, floccose granules. *Flesh* yellow, turning dark blue on exposure to air, except in base of stipe where it is red and unchangeable.

Habitat in sandy soil, beneath oak, Heath and Reach, near Leighton Buzzard, Beds., 1952.

In view of the doubts expressed by continental mycologists as to the true status of *B. discolor*, it is very unfortunate that only a painting remains. The original specimen was sent to the late A. A. Pearson, and decayed *en route*. Gilbert (1936), after studying Bourdot's notes and painting of a specimen, determined by Quélet as *Dictyopus luridus* var. *discolor*, stated that in his opinion the fungus represented *B. queletii* Schulz. This strengthened his conviction that *B. discolor* should be regarded as a synonym of *B. queletii*. Gilbert & Leclair (1942) again stated that they regarded these two names as synonyms; a view to which Imler (1950) subscribed. As the fungus described above matches so closely Quélet's (1888) original

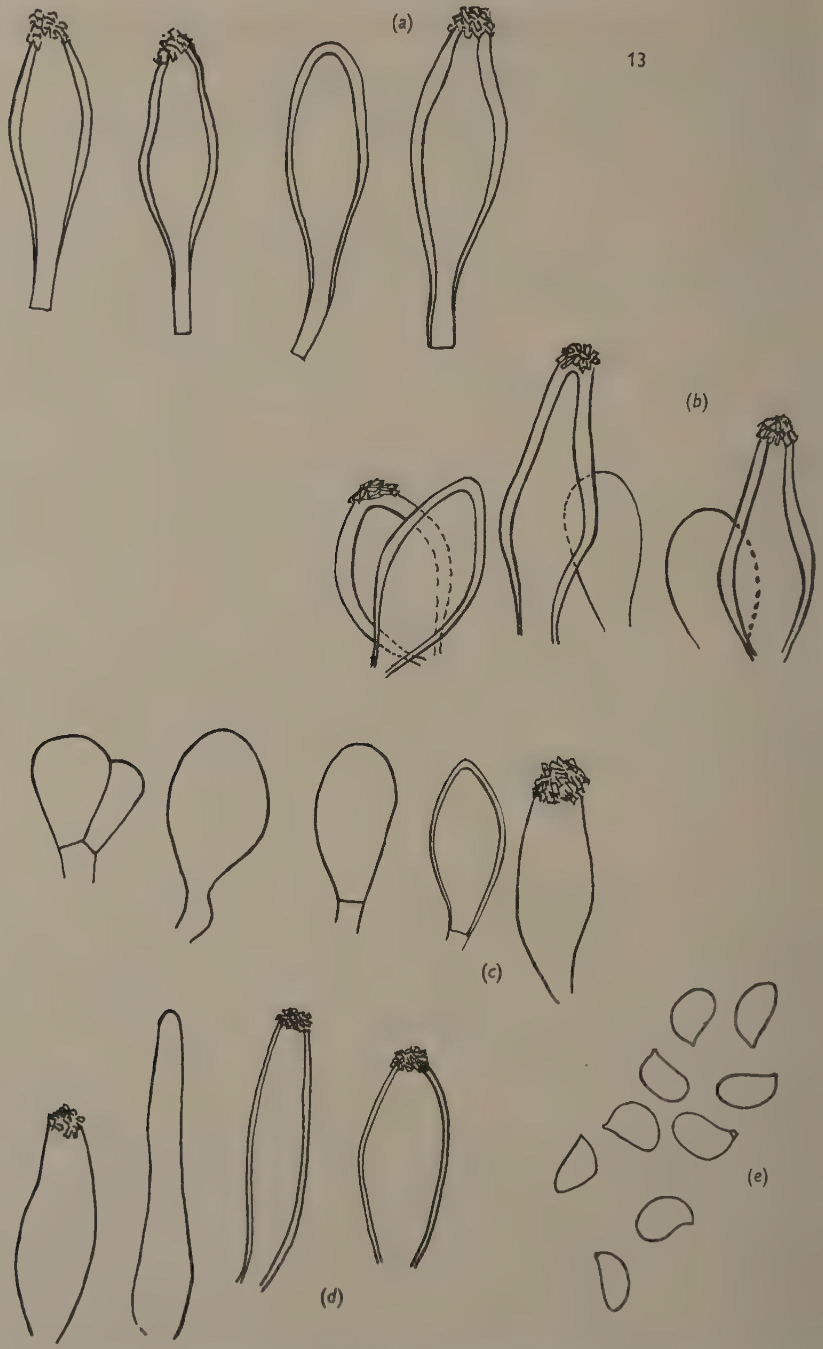


Fig. 13. *Inocybe hirtella*: (*a*) cheilocystidia; (*b*) cheilocystidia and paracystidia on gill edge; (*c*) caulocystidia from extreme base of stipe; (*d*) caulocystidia from lower third of stipe; (*e*) spores. All ×866.

description of *B. discolor*, it was decided to adopt this name. It may well be that it is only a form of *B. queletii*, but if so it is a very beautiful and striking colour variant, which has not, hitherto, been reported from Britain. The only other species with which this fungus is likely to be confused is *B. junquilleus* (Quél.) Boud., but this differs in spore characters, and in having yellow pores.

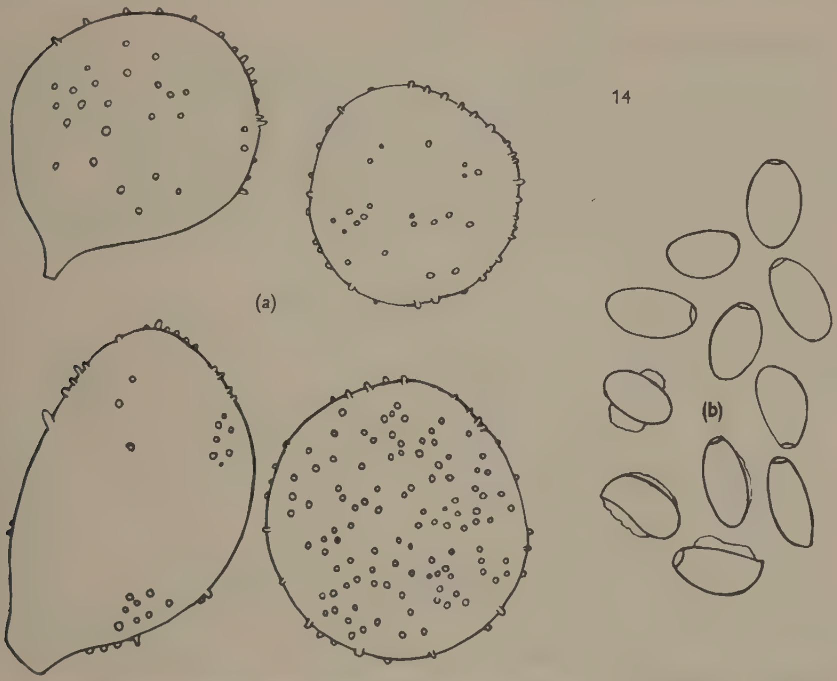


Fig. 14. *Coprinus martinii*: (*a*) cells forming mealy covering to cap; (*b*) spores. ×866.

Cyphella lactea Bres., in *Fung. Trid.* **1**, 61, 1884

Sporophore 0·2 cm. high, 0·2 cm. wide, sessile, bell-shaped, erect or pendulous, white externally, but with cream tinge to inner, or hymenial surface. *Spores* elliptical-lanceolate, with narrow curved base, 12–15 × 3–4 μ. *Structure* seen in section to consist of hymenium 26–33 μ wide, subhymenium 13–15 μ wide, and context of variable thickness formed of parallel, septate, clamped, hyaline hyphae, 2–3 μ wide. From the outermost hyphae of the context, there arise others which are branched, septate, and clamped, forming a loose tangled weft. These give rise to certain branches that grow out to form characteristic clavate hairs, up to 39 μ long, and 2 μ wide, with swollen heads 3–6 μ in diameter, which may or may not be septate, but if so these septa lack clamps, and are therefore secondary. The total thickness of the sporophore is up to 80 μ.

Habitat on old, wet culms of *Glyceria aquatica*, Leighton Buzzard, Beds., 6 July 1953.

Rea (1922) listed *C. lactea* as growing on dead leaves of *Aira caespitosa* in June, and stated that it was uncommon. This presumably referred to his earlier report on the fungus (Rea, 1908) from Tumby, Lincs., on dead leaves of *Aira caespitosa*, coll. H. C. Hawley, June 1908, which was the first record for Britain. However, despite the very few collections made in this country, the fungus is probably not uncommon on rotting grass culms in very damp places.

Clavaria ligula Fr. in *Syst. Myc.* **1**, 477, 1821

Sporophore up to 7 cm. high, 0·8 cm. wide at apex, narrowing gradually to white, villose base, simple, without distinct stipe, clavate, laterally compressed, rugulose, ochraceous. *Basidia* four-spored, up to 62 μ long, 9 μ wide. *Spores* 8–15 × 4–5 μ, hyaline, subcylindrical to pip-shaped. *Hyphae* monomitic, thin-walled, septate, 3–16 μ wide, with clamps.

Habitat in leaf litter, on raised tussock at base of Silver Birch tree, in swamp, Rothiemurchus Forest, Inverness-shire, coll. P. M. Reid, 29 August 1953.

This species is very similar to *C. pistillaris* Fr., but differs from it in its less robust appearance, much shorter basidia, and smaller, narrower spores. The first British record of *C. ligula* was that of Berkeley & Broome (1879) from Strachan (misspelled as Straan), Kincardineshire, coll. J. Sim. This collection, preserved in the Kew Herbarium, has been examined, and found to be correctly named. Other published records include Cotton & Wakefield (1918), Duncombe Park, near Helmsley, Yorks. (Y.N.U. foray), September 1903; Bramley (1952), Fountains Abbey, Yorks. (Y.N.U. foray), September 1951; specimens from these two collections have been examined and found to be *C. pistillaris*. Further reports are those of Swanton (1934), West Pepperharrow Common, Haslemere, Surrey; Worcs., 17 September 1903; Wyre Forest, Worcs., 5 October 1904, but no specimens of these gatherings would seem to have been preserved.

The author wishes to express his thanks to Dr E. J. H. Corner for confirming his determination of the Rothiemurchus material cited above.

REFERENCES

BERKELEY, M. J. & BROOME, C. E. (1879). Notices of British Fungi. *Ann. Mag. nat. Hist.*, Ser. 5, **3**, 202–212.

BRAMLEY, W. G. (1952). The autumn fungus foray at Ripon. *Naturalist, Lond.*, no. 842, 130.

BULLIARD, J. B. F. (1812). *Herbier de la France.* Seconde Division. *Histoire des Champignons.* Tome Seconde. Paris.

COOKE, M. C. (1881–3). *Illustrations of British fungi.* London, Williams and Norgate.

COTTON, A. D. & WAKEFIELD, E. M. (1918). A revision of the British Clavariae. *Trans. Brit. mycol. Soc.* **6**, 164–198.

DENNIS, R. W. G. (1948). Higher fungi of Wester Ross. *Trans. bot. Soc. Edinb.* **34**, 397–401.

FRIES, E. M. (1874). *Hymenomycetes Europaei.* Upsala.

GILBERT, E. J. (1936). Notules sur les Bolets. Première série. *Bull. Soc. mycol. Fr.* **52**, 249–260.

GILBERT, E. J. & LECLAIR, A. (1942). Notules sur les Bolets. Troisième série. *Bull. Soc. mycol. Fr.* **58**, 170–189.

HEIM, R. (1931). *Le genre Inocybe*. Paris: Lechevalier.

IMLER, L. (1950). Recherches sur les Bolets. *Bull. Soc. mycol. Fr.* **66**, 177–203.

KÜHNER, R. & ROMAGNESI, H. (1953). *Flore Analytique des Champignons Supérieurs*. Paris: Masson.

LANGE, J. E. (1935). *Flora Agaricina Danica*, **1**. Copenhagen: Recato.

MÉTROD, G. (1939). Quelques espèces du Genre Tricholoma. *Rev. Mycol.* **4**, 101–118.

PEARSON, A. A. (1938). Agarics. New records and observations. *Trans. Brit. mycol. Soc.* **22**, 27–46.

PEARSON, A. A. & DENNIS, R. W. G. (1948). Revised List of British Agarics and Boleti. *Trans. Brit. mycol. Soc.* **31**, 145–190.

QUÉLET, L. (1888). *Flore mycologique de la France*. Paris: Doin.

REA, C. (1908). New and rare British Fungi. *Trans. Brit. mycol. Soc.* **3**, 124–130.

REA, C. (1922). *British Basidiomycetae*. Cambridge University Press.

REID, D. A. (1952). New Bedfordshire fungi. *Beds. Nat.* **6**, 35.

SWANTON, E. W. (1934). *A list of the fungi of the Haslemere District*. Haslemere Natural History Society.

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Trans. Brit. mycol. Soc. **38** (4), 400–404 (1955)

THREE NEW BRITISH AGARIC RECORDS

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(With 1 Text-figure)

Descriptions and figures are given of three toadstools not previously recorded from Britain. They are (with place and date of original description): *Pholiota albo-crenulata* Peck (N. America, 1873); *Hygrophorus hymenocephalus* Smith & Hesler (N. America, 1942); *Hygrophorus quietus* Kühner (France, 1947).

All three species were taken on an Autumn Day Foray organized by The British Mycological Society at Juniper Hall, near Boxhill, Surrey, on 23 October 1954. The accompanying descriptions are from the living British material. This was, however, rather limited, and supplementary information, given here in inverted commas, has been added from earlier publications. All illustrations are from our own preparations of fresh specimens.

Pholiota albo-crenulata Peck, *Bull. Buffalo Soc. Nat. Sci.* **1**, 49 (1873). (Fig. 1 *a–d*)

Syn. *P. fusca* Quélet, *4e Supplement à Champignons du Jura et des Vosges* in *Bull. Soc. Bot. Fr.* **23**, 1876.

Illustr. Harper, E. T., *Trans. Wis. Acad. Sci. Arts Lett.* **17**, 1912, pls. 42, 43.

CAP '3'–6·5–14 cm., at first 'convex and more or less umbonate' then expanded and more or less umbonate, *reddish date brown or reddish rusty umber*, *very viscid*, cuticle rather thick *tough and elastic*, *with adpressed pale bistre* ('darker becoming whitish') *fibrillose scales*, especially near margin; margin even, exceeding gills, often narrowly reflexed, 'appendiculate when young'. GILLS adnate slightly emarginate or with tooth, broad near stem but not ventricose, crowded, *greyish then pale pallid olivaceous*, later tinged deep reddish umber especially at edge; *edge at first thick*, *white and often with white milk-like drops giving a more or less granulated appearance*. STEM '5'–8·0–17/1·3–1·5 cm., more or less cylindrical (slightly swollen at the base), *dry*, whitish to pallid or slightly ochraceous, *with squarrose dark brown scales up to a more or less fugacious*, *torn*, *fibrillose ring*, apex pruinose white, *often also with white milk-like drops* and striate from the gills. FLESH pale yellowish, whitish or tinged olivaceous in cap, darker in stem, pale pallid or bistre or bistre buff or wood brown in cortex. SMELL faint pleasant. TASTE more or less bitter. SPORES 11–14/'5·5'–6·0–7·0 μ, *ventricose amygdaliform*, thick walled, *umber or cocoa brown in mass*. BASIDIA 4-spored. GILL EDGE sterile with *conspicuous cylindrical or slightly clavate cells* 6–11·0 μ wide, *forming a thick white edge*, often also with milk-like globules *sub. micr*. TRAMA of gill regular. HYPHAE of cap scales 1·0–2·0 (3) μ wide, agglutinated.

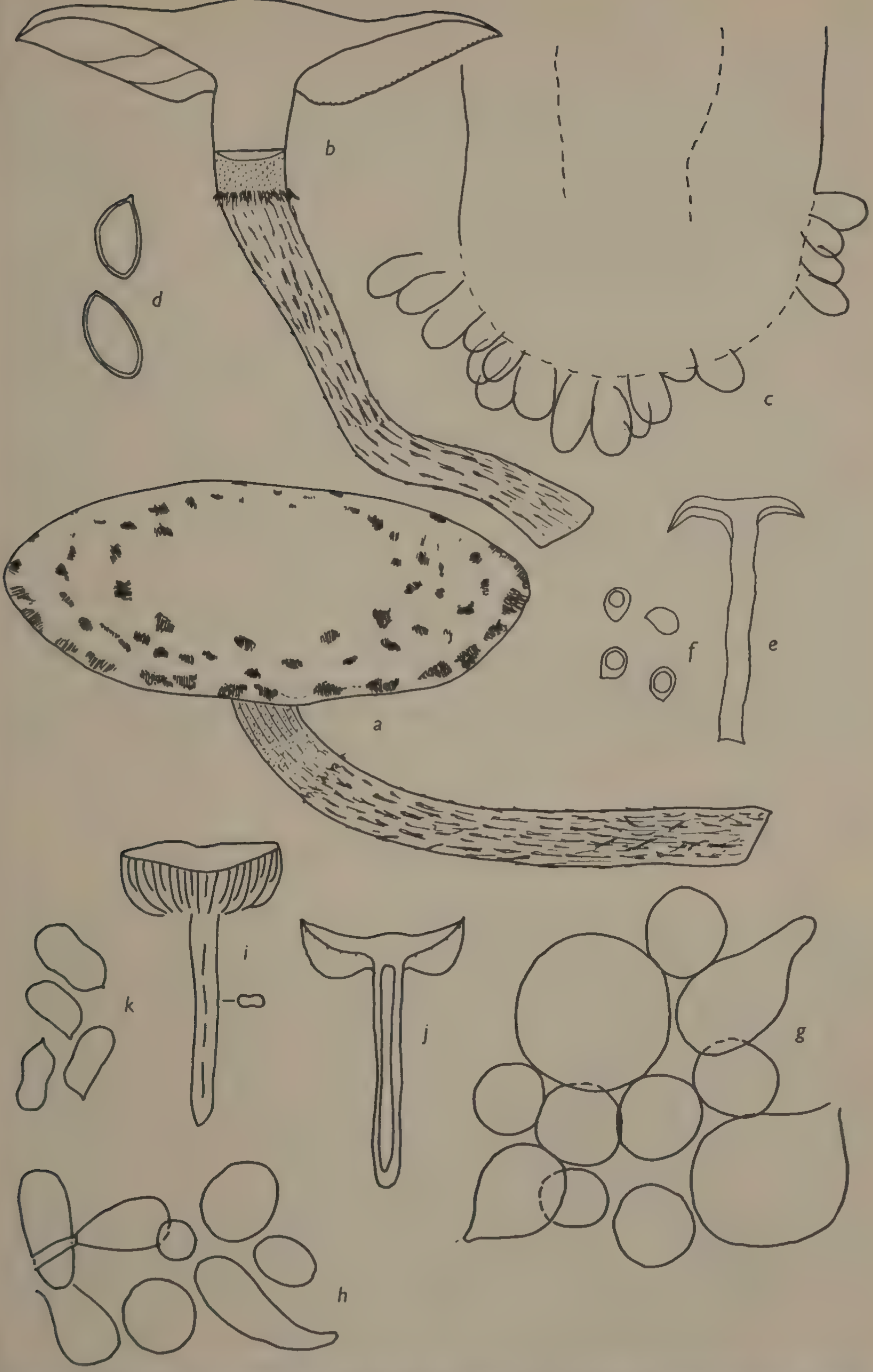

Fig. 1 *a–d*. *Pholiota albo-crenulata*. *a*, whole fruit-body, × ½; *b*, ditto, showing section through cap, × ½; *c*, section through gill showing marginal cystidia, × 500; *d*, spores, × 1000. *e–h*, *Hygrophorus hymenocephalus*. *e*, section through whole fruit-body, × 1⅓; *f*, spores, × 1000; *g*, surface section of cap cuticle towards margin, × 500; *h*, ditto, at disk, × 500. *i–k*, *Hygrophorus quietus*. *i*, whole fruit-body, × ½; *j*, ditto, in section, × ½; *k*, spores, × 1000.

At foot of *living* beech (*Fagus*), Boxhill, Surrey; two specimens growing together. *Legit* Miss Noreen Parker, King's College, London.

Observations. Easily recognized by its dark viscid cap with more or less conspicuous adpressed scales, greyish gills with granulated white edge, dry stem and large ventricose amygdaliform spores. Not likely to be confused with any other British species.

In Europe, this species would appear to be very rare, having been reported on only three previous occasions: twice in France (Quélet, *loc. cit.* 1876 as *P. fusca* sp.nov.; Pouchet, 1934), and once in the Carpathian mountains (Pilat, 1936). According to Singer (1939), it has been observed by Killerman in Bavaria. It is, perhaps, significant that, apart from the record by Quélet, the only European floras mentioning this very striking species are those of Pilat (1951) and Kühner & Romagnesi (1953), the latter saying 'very rare'. According to Josserand & Smith (1937), the 'species is not rare in the United States'. A full account of the identity of *P. albo-crenulata* Peck with *P. fusca* Quélet is given by Josserand (1937) and referred to in Josserand & Smith (1937). Since Peck's name ante-dates that of Quélet by no less than 3 years, it is surprising that Kühner & Romagnesi should adopt the later binomial.

In North America, the species is described as growing singly or in groups of two or three, and according to Kauffman (1918) always at the foot of *living* trees, but Peck reports it also, but more rarely, from dead trunks or stumps. In North America, it is found most commonly on Sugar Maple (*Acer saccharatum* Marsh.), less often on Yellow Birch (*Betula lutea* Mchx.) and once on Hemlock (*Tsuga*). Quélet reported it from conifers and Pilat from Silver Fir (*Abies alba* Miller).

Hygrophorus hymenocephalus Smith & Hesler, *Lloydia*, 5, 14 (1942).
(Fig. 1 *e–h*)

CAP '5'–14·0–'30' mm., convex, then convex expanded and slightly depressed, *unicolorous*, *umber when moist*, *drying paler*, sepia on disc with greyish 'or clay buff' margin; disc *sub. lente* minutely fibrilloso-squamulose, remainder opaque, *atomate when dry*, margin crenate 'at first', often splitting or 'becoming lobed'. GILLS *narrowly arcuate-decurrent*, concolorous but paler, distant, rather thick, occasionally forking at base, edge thin concolorous, even. STEM 26·0–'80'/2·0–'7' mm., concolorous, minutely white silky striate *sub lente* but shiny, *apex smooth*, equal 'or attenuated below', flexuose, stuffed, fragile, base very slightly white tomentose. FLESH when moist concolorous, drying whitish. SMELL faint, not unpleasant. SPORES subglobose to shortly ovate 4·0–5·0/3·75–4·0 μ (4·0–5·5/4·0–4·5 μ sec. Smith and Hesler), often 1-guttulate, smooth. BASIDIA rather narrow, '34–45/6–7' μ sec. Smith & Hesler, 4-spored. CYSTIDIA absent. TRAMA of gill interwoven. CUTICLE of cap typically *cellular-hymeniform* at margin, cells 10–40 μ diam., but here and there, especially towards disk with a few cylindrical or cylindrical-clavate cells.

In grass, near a larch plantation, Happy Valley, Juniper Hill, near Boxhill, Surrey; one specimen. *Legit*: Dr N. J. G. Smith.

Observations. The interwoven gill trama places this species in the section *Camarophyllus*. The new combination under this section at the generic level has been made by Lange (1949–50) who published the first European record of the species. His specimens (from Denmark) were interesting in showing mostly 2-spored basidia and consequently larger spores: 5·4–7·5/4·5–5·5 μ. Smith & Hesler do not mention 2-spored basidia in their diagnosis, nor did we observe them. The species is closest to *H. atropunctus* (Pers. ex Fr.) Smith & Hesler (Fr., *Eccilia*; Sacc., *Omphalia*; Lange, *Camarophyllus*; Kühner, *Tricholoma*) which has essentially the same cuticular structure, very similar spores and also 2- and 4-spored basidia. It is, however, distinct in having brownish black granular flocci, made up of septate hyphae, in the upper half of the stem. Furthermore, according to F. H. Møller, as quoted by Lange (1949–50), the basidia of *H. atropunctus* are considerably shorter in both 2- and 4-spored forms. Nevertheless, the possibility must not be lost sight of, that more extensive gatherings of these two species may eventually show that they are conspecific or that *H. hymenocephalus* is not deserving of more than varietal rank. *H. foetens* Phill. differs by the strong faecal smell and smaller spores of a different shape. *Omphalia clusiliformis* Kühner & Romagn. (= *O. clusilis* sensu K. & M.) is similar but is paler and has a smell of meal and spores larger even than the 2-spored form of *H. hymenocephalus*.

It will be evident that the systematic position of *H. hymenocephalus*, as well as that of *H. atropunctus*, is a matter of considerable difficulty. Singer (1949) refers the former and 'perhaps also' the latter to *Armillariella* Karst. For the present, we prefer to retain them in *Hygrophorus* mainly on account of the thick and distant gills.

Hygrophorus quietus Kühner, *Ann. Sci. Franche-Comté*, **2**, 19 (1947). (Fig. 1 *i–k*)

CAP '1·2'–4·2–5·2–'7·5' cm., narrowly convex then expanded and sometimes slightly depressed round a broad umbo, sulphur or rich yellow to somewhat orange to reddish orange, expallent rather than hygrophanous, *not viscid*, but greasy to touch (like cap of *Collybia butyracea*). GILLS thick, distant, ventricose, adnate-emarginate, yellowish but mainly tinged orange towards base. STEM up to 60/10 mm. concolorous with cap, moist but *not viscid*, sometimes compressed, smooth. SPORES white in the mass, smooth, contents granular, often 1-guttulate, oblong, rounded at each end, *constricted at middle* especially when seen in dorsi-ventral view, 8·5–10(12)/4·5–5·0(5·5) μ, 3·4–4·0 μ at constriction. BASIDIA 4-spored. TRAMA of gill regular, cells up 50/20 μ. CUTICLE of cap filamentous. SMELL, especially when rubbed, *remarkably like that of Lactarius quietus*, but stronger.

In grass, on Juniper Hill, near Boxhill, Surrey. Also found previously in chalk pasture, Langcliffe Brow, Settle, Yorks, 19 September 1953. Probably calcicole.

Observations. As far as we are aware, no other species with which *H. quietus* is likely to be confused has the same unmistakable smell. When to this are added the constricted spores and absence of viscid cap or stem, the taxon becomes even more clearly defined. The species is likely to prove generally distributed and an excellent illustrated account from Swiss material has recently been published by Haller (1952; c.f. also Haller, 1954). In the past it is probably one of a number of species which have been referred to *H. obrusseus*, *H. chlorophanus* or even *H. coccineus*, none of which has the characteristic smell or constricted spores. *H. reai* has slightly constricted spores but lacks the smell; moreover, it has a viscid stem and is intensely and immediately bitter to the taste. (*H. reai* var. *insipida* has no characteristic smell or taste and we are not satisfied that it is correctly referred as a variety of *H. reai*.) *H. aurantiosplendens*, a species described by Haller (1954), also has constricted spores and is clearly not unlike *H. quietus*. It is, however, much larger and has a viscid cap. The characteristic smell is again absent. This particular species has already been found by one of us (P. D. O.), also in chalk pasture, at Gomshall, Surrey, 18 October 1953, and an account of it will be given later.

REFERENCES

HALLER, R. (1952). *Hygrophorus quietus* Kühner. *Schweiz. Z. Pilzk.* p. 180.

HALLER, R. (1954). Beitrag zur Kenntnis der schweizerischen Hygrophoraceae. *Schweiz. Z. Pilzk.* pp. 81–91.

JOSSERAND, M. (1937). A propos de l'existence en Europe de *Pholiota albocrenulata* Peck. *Rev. Mycol., Paris*, N.S., **2**, 18.

JOSSERAND, M. & SMITH, A. H. (1937). Notes on the synonomy of French and American agarics. I. *Mycologia*, **29**, 722.

KAUFFMAN, C. H. (1918). *Agaricaceae of Michigan*, **1**, 301. Michigan Geological and Biological Survey (Publication 26; Biological series 5).

KÜHNER, R. & ROMAGNESI, H. (1953). *Flore Analytique des Champignons Supérieurs*, p. 327.

LANGE, MORTEN. (1949–50). Notes on Danish Fungi. *Friesia*, **4**, 63.

PILAT, A. (1936). Sur la récolte du *Pholiota albocrenulata* Peck, américan, dans les Carpathes. *Rev. Mycol.*, N.S., **1**, 303.

PILAT, A. (1951). *Klic... (Agaricalium Europaeorum Clavis Dichotomica)*, p. 358.

POUCHET, A. (1934). *Pholiota albocrenulata* Peck. *Ann. Soc. Linn. Lyon*, **78**, 101.

SINGER, R. (1939). Notes sur quelques Basidiomycètes. *Rev. Mycol., Paris*, N.S., **4**, 72.

SINGER, R. (1949). The Agaricales (Mushrooms) in Modern Taxonomy. *Lilloa*, **22**, 217.

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HENDERSONIA TYPHAE THE CONIDIAL STATE OF *LEPTOSPHAERIA TYPHARUM*

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(With 1 Text-figure)

Hendersonia typhae Oudemans has been shown to be the conidial state of *Leptosphaeria typharum* (Desm.) Karst. The evidence suggests that *Phoma typharum* Sacc. is not related to *Leptosphaeria typharum*.

Leptosphaeria typharum (Desm.) Karst.

Perithecia subepidermal, arranged singly or in groups between the veins, globose, dark brown to black, 120–160 μ in diameter, ostiole inconspicuous, wall 10–20 μ thick, composed of brown polygonal cells about 10 μ wide (Fig. 1 A). *Asci* broadly club-shaped or elliptical, sessile, 8-spored, bitunicate, 80–96 × 22–26 μ. *Ascospores* biseriate, inequilateral, curved, 3-septate, the second cell enlarged, constricted at the septa, yellow to pale brown in colour, thick-walled, 22–32 × 9–11 μ (usually 28–30 × 10 μ) (Fig. 1 B). The above description is based on a collection on dead leaves of *Typha latifolia*, Little Sea, Studland, Dorset, 9 September 1954 (Herb. Sheffield no. 1390). This specimen has been matched with:

(1) Desmazières, *Plantes Cryptogames de France*, edit. 2, ser. 1, no. 1428. *Sphaeria scirpicola* var. *typharum* (Fig. 1 C).

(2) Rabenhorst, *Herb Mycologicum*, edit. 2, no. 731. *Sphaeria typharum* (Desm.) Rabenh. This specimen also bore conidia.

Both exsiccati were cited by Karsten (1871), who transferred the fungus to the genus *Leptosphaeria*. Examination of a specimen from Karsten's Herbarium, however, failed to yield perithecia.

Hendersonia typhae Oud.

Cultures were prepared from single ascospores of specimen 1390 and transferred to oat agar slopes on 2 October 1954. The fungus grew rapidly, forming a black mycelium with occasional white aerial hyphae. In 6-week-old cultures numerous pycnidia were seen (Fig. 1 D). The pycnidia are simple or compound structures with several loculi; variable in size (up to 350 μ in diameter) and shape. The wall is composed of about five layers of olive-brown flattened cells lined by three to five layers of hyaline prismatic cells. Spores arise by proliferation of the prismatic cells (Fig. 1 E). Mature spores are variable in shape, but typically obclavate or leech shaped, with 3–8 septa (usually 5-septate), yellow to brown in colour, rather thick-walled, constricted at the septa, and terminating in a tapering

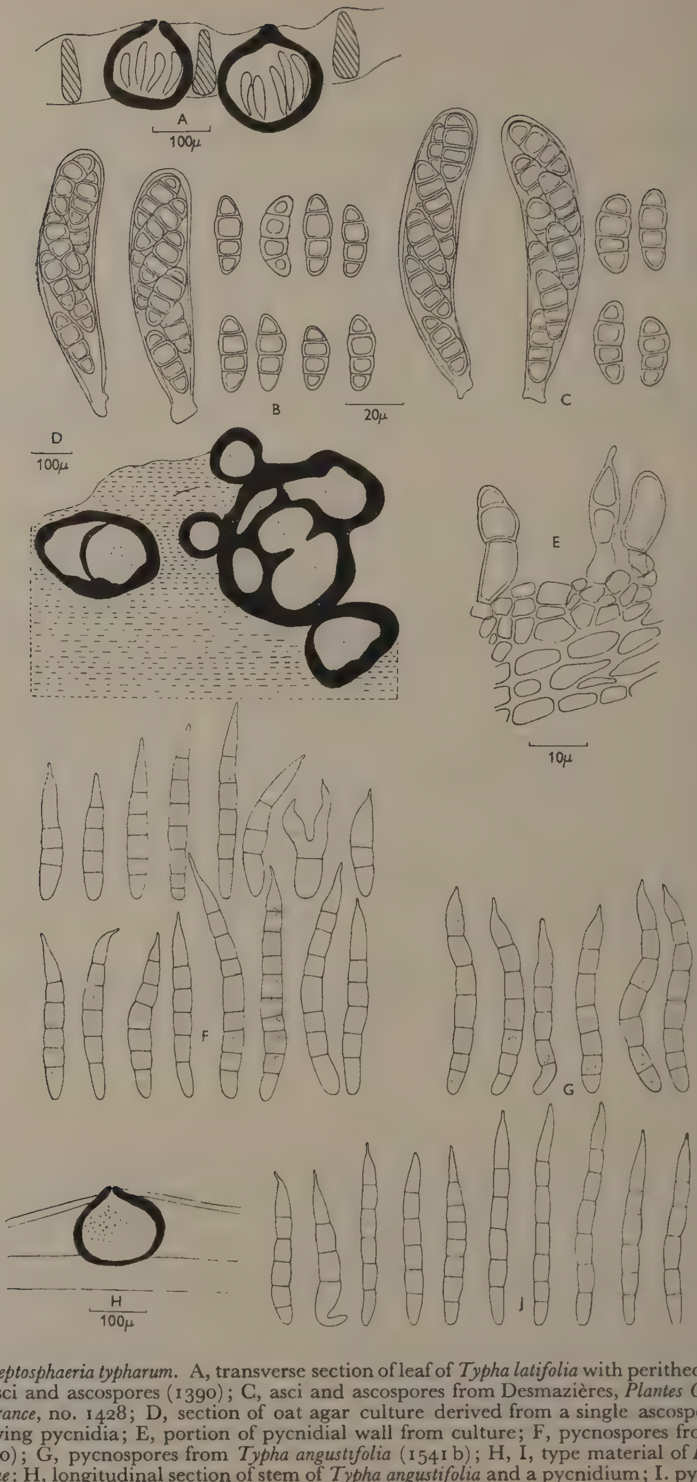

Fig. 1. *Leptosphaeria typharum.* A, transverse section of leaf of *Typha latifolia* with perithecia (1390); B, asci and ascospores (1390); C, asci and ascospores from Desmazières, *Plantes Cryptogames de France*, no. 1428; D, section of oat agar culture derived from a single ascospore (1390) showing pycnidia; E, portion of pycnidial wall from culture; F, pycnospores from culture (1390); G, pycnospores from *Typha angustifolia* (1541 b); H, I, type material of *Hendersonia typhae*: H, longitudinal section of stem of *Typha angustifolia* and a pycnidium; I. pycnospores. B, C, F, G, I to same scale.

appendage about 4μ long. The range in size of conidia from culture was $30–90 \times 6–8\mu$ (usually $60–70 \times 7\mu$) (Fig. 1F).

Similar conidia were collected with perithecia on fallen stems of *Typha angustifolia* from Blelham Tarn, 29 May 1954 (Herb. Sheffield no. 1541). The conidia were 5–7 septate, cylindrical to obclavate, constricted at the septa, yellow to pale brown in colour, $58–75 \times 7–9\mu$. Cultures were prepared from single conidia and ascospores and transfers made to oat agar slopes on 19 November 1954. Cultures derived from either ascospores or conidia were identical in appearance. When examined 1 month later, both types of culture had produced pycnidia similar to those described above. Pycnospores up to 120μ long were found.

The pycnidia match the description of *Hendersonia typhae* Oudemans (1873*a*, *b*) described from *Typha angustifolia* in association with a *Phoma* and *Sphaeria scirpicola*, and have also been matched with:

(1) *Hendersonia typhae* Oud. The type specimen bore both pycnidia and perithecia. Pycnospores were 3–7 septate, $40–70 \times 6–8\mu$ (Fig. 1H, I).

(2) Kabát & Bubák, *Fungi Imperfecti Exsiccati*, no. 264. Pycnospores $70–100 \times 6–7\mu$. Bubák & Kabát (1905) state that this collection was authenticated by Oudemans and gives spores as $50–115\mu$ long.

(3) Sydow, *Mycotheca germanica*, no. 1130. Pycnospores $60–74 \times 6–7\mu$, 5–7 septate.

(4) Sydow, *Mycotheca germanica*, no. 3178. Pycnospores $50–74 \times 7–8\mu$, 5–7 septate. Perithecia were also present, as noted by Sydow on the Herbarium packet.

von Höhnel (1909) transferred *Hendersonia typhae* to *Scolecosporium*, whilst Petrak (1921) erected the genus *Scolecosporiella* for it. Grove (1918) described a variety *major* with spores 5–9 septate, $60–80 \times 7\mu$.

Phoma typharum Sacc.

Phoma typharum Sacc. is frequently associated with both *Leptosphaeria typharum* and *Hendersonia typhae*. It occurs on the type specimen of *H. typhae* and also on specimen no. 1541. Trail (1887) records *Phoma typharum* 'along with *Leptosphaeria typharum*, of which it is probably the spermogonium'. Grove (1935) also records *Phoma typharum* 'in company with *Leptosphaeria typharum* Karst., of which it is the spermogonial stage'. The experiments described above, however, suggest that *Phoma typharum* is not genetically connected with *Leptosphaeria typharum*. Cultures started from pycnospores of *Phoma typharum* grew readily in oat agar cultures, forming *Phoma* pycnidia within one month, but no fruit bodies resembling those of *Leptosphaeria typharum* have been found.

It is a pleasure to acknowledge the loan of specimens from the British Museum (Natural History), the Royal Botanic Gardens, Kew, the Botanic Gardens, Amsterdam and from Karsten's Herbarium.

REFERENCES

Bubák, F. & Kabát, J. E. (1905). Mykologische Beiträge. III. *Hedwigia*, **44**, 350–358.

Grove, W. B. (1918). New or noteworthy fungi. Part 6. *J. Bot., Lond.*, **56**, 314–321.

Grove, W. B. (1935). *British stem- and leaf-fungi (Coelomycetes).* **1**. *Sphaeropsidales.* Cambridge University Press.

Höhnel, F. von (1909). Fragmente zur Mykologie 6. *S.B. Akad. Wiss. Wien*, **118**, 1–78.

Karsten, P. A. (1871). Mycologica Fennica. II. Pyrenomycetes. *Bidr. Finl. Nat. Folk*, pp. 1–250.

Oudemans, C. A. J. (1873*a*). Matériaux pour la flore mycologique de la Néerlande. II. *Arch. néerl. Sci.* **8**, 343–416.

Oudemans, C. A. J. (1873*b*). Aanwinsten voor de Flora Mycologica van Nederland. *Ned. kruidk. Arch.* Ser. 2, **1**, 252–267.

Petrak, F. (1921). Mykologische Notizen. II. *Ann. Mycol., Berl.*, **19**, 17–128.

Trail, J. W. H. (1887). Revision of Scotch Sphaeropsidae and Melanconiae. *Scot. Nat.* **9**, 110–128.

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CALCARISPORIUM ARBUSCULA LIVING AS AN ENDOPHYTE IN APPARENTLY HEALTHY SPOROPHORES OF *RUSSULA* AND *LACTARIUS*

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Calcarisporium arbuscula can frequently be isolated by tissue-culture methods from the flesh of healthy fruit-bodies of species of *Russula* and *Lactarius*. It appears to live in the growing fruit-bodies as an endophyte, without causing any apparent disease. When the growth of the infected host is checked, or ceases as it becomes old, the endophyte reveals its presence by producing its reproductive bodies all over the surface of the agaric.

Calcarisporium arbuscula Preuss was frequently isolated during attempts to grow species of *Russula* in pure culture, using tissue from the interior of young fruit-bodies as inocula. The only other colonies which developed, apart from obvious contaminants, were slow-growing and produced no spores. These were probably the mycelia of the agarics, although no clamp-connexions could be seen.

Calcarisporium arbuscula has previously been recorded as a parasite on various fleshy fungi. There seems to be no report of the isolation of the mould from apparently healthy sporophores, and this paper is concerned with a study of the relationship between *C. arbuscula* and species of *Russula* and *Lactarius*.

METHODS

The fruit-bodies of *Russula* and *Lactarius* were usually wrapped separately in paper immediately after picking, or were collected individually in sterile containers, to prevent cross-infection, although these precautions were later found to be unnecessary.

Small pieces of flesh from the interior of the sporophore, exposed by breaking, were cut out with a sterile scalpel and placed on agar.

The earlier isolations were made on 2 % malt agar, but later, after trials with various media, the following was found to give the best results: glucose, 20 g.; KH_2PO_4, 1 g.; $MgSO_47H_2O$, 0·5 g.; ammonium tartrate, 3 g.; yeast extract (Difco), 0·5 g.; $FeCl_3$ (1 % solution), 0·5 ml.; $ZnSO_4$ solution (1 part Zn/500, w/v), 0·5 ml.; agar, 20 g.; distilled water, 1000 ml.

After 5–7 days' incubation at 20° C., the inocula from which *Calcarisporium* was growing could be clearly distinguished. Usually, each isolate was then subcultured on to a fresh agar plate to determine the colony type and, in some cases, single-spore isolates were prepared.

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Inocula, from which no *Calcarisporium* was produced often gave, after several weeks, sterile colonies, which are believed to be the mycelia of the agarics. Some of these have been kept in culture, but most soon ceased to grow and did not survive subculturing.

IDENTIFICATIONS

For the identification of the species of *Russula* and *Lactarius* the papers by Pearson (1948, 1950) proved the most useful.

Russula emetica was considered as four forms, a birchwood form being distinguished in addition to the three given by Pearson. This small, fragile, rosy-pink form appeared to be distinct, although it does not seem to have been considered as separate before.

Calcarisporium arbuscula is a very characteristic species which has recently been re-described by Hughes (1951). An isolate made in the present study has been deposited at the Commonwealth Mycological Institute (Herb. I.M.I. 55742).

RESULTS

Calcarisporium has been isolated from many of the species of *Russula* tested, including species from all the groups into which the genus is usually divided (Pearson, 1948). Few attempts have been made to obtain it from fruit-bodies of *Lactarius*, but it has been isolated from two species. These results are shown in Table 1. The number of infected fruit-bodies may actually be larger, as bacterial contamination may have prevented *Calcarisporium* from growing out from some of them.

Table 1. *Summary of isolations of* Calcarisporium *from* Russula *and* Lactarius

Host	No. fruit-bodies sampled (all ages)	No. from which *Calcarisporium* was obtained
R. emetica (oakwood form)	152	36
R. ochroleuca	350	31
R. emetica (birchwood form)	101	22
R. fragilis	66	12
R. fellea	64	9
R. versicolor	10	4
R. sororia	24	2
R. lepida	4	2
R. vesca	7	1
R. nigricans	6	1
R. claroflava	2	1
Other *Russula* spp.	436	17
L. rufus	28	7
L. torminosus	14	2
Totals	1264	147

It does not seem to be restricted to a small number of localities, having been isolated from nearly all the areas visited, as shown in Table 2.

All the isolations from sporophore tissue were made from apparently perfectly healthy fruit-bodies. The gills of some, which were afterwards shown to contain the endophyte throughout the fruit-body, were examined microscopically. They appeared to be quite normal, apart from a very few conidiophores of *Calcarisporium* in two individuals. The presence of the mould did not seem to be correlated with damage to the sporophore by maggots or other animals, although inocula from such specimens showed contamination more frequently than those from undamaged ones.

Table 2. *Geographical distribution of isolates of* Calcarisporium

Locality	No. fruit-bodies sampled (all ages)	No. from which *Calcarisporium* was obtained
Ruislip Woods, Middx.	439	51
Clayton Wood, near Leeds	133	32
Boxhill area, Surrey	246	16
Leith Hill area, Surrey	153	14
Hampstead Heath, near London	68	13
Hayes Common, Kent	89	10
Eight other areas	136	11

When several inocula were tried from different parts of a fruit-body, if *Calcarisporium* did appear, it usually grew from all of them.

The fruit-bodies studied were classified roughly into groups, according to size and stage of development. In species where sufficient numbers were studied, *Calcarisporium* could usually be isolated from about 5–15 % of the 'young' fruit-bodies, and 10–40 % of the 'young-mature' and 'mature' ones.

Infected fruit-bodies, usually at the 'old-mature' stage, could be found in nature covered with conidiophores and sclerotia of *Calcarisporium*, but no numerical records of these were kept. An attempt was made to watch the development in the field of fruit-bodies known to be infected, but this was unsuccessful. It was then thought that the effects on the host in nature might be similarly produced if they were collected and kept for a short time. After collection, a small portion of the flesh of each fruit-body was removed and used to test for the presence of the endophyte in the usual way. The fruit-bodies were then kept in separate containers in the laboratory. After several days, the ones containing the endophyte became covered with the characteristic conidial apparatus of *Calcarisporium*, in the few cases where secondary infection by moulds such as *Verticillium* did not mask the effects. *Verticillium* commonly appeared on fruit-bodies kept in the laboratory irrespective of whether or not they were already infected with *Calcarisporium*.

Calcarisporium seems to be capable of dominating the host without the co-operation of other parasites, when the host's growth is stopped, or its vigour declines after maturity. This is shown by the fact that inocula from within such fruit-bodies rarely produced any organisms apart from *Calcarisporium*.

Attempts to see the mycelium of the endophyte in sections of sporophores were unsuccessful owing to the complexity of hyphal systems in *Russula*.

The isolates of *Calcarisporium* were of a number of different types. The clearest distinction was between those producing very numerous black sclerotia, and a smaller number (about 10% of the isolates) which produced no black sclerotia on the medium used. The larger group can be considerably subdivided on the bases of various less well-marked colony characters. These different types seem to be distributed in quite a random manner. In several cases where close groups of the agaric were studied, isolates of different types were obtained from adjacent fruit-bodies. However, inocula from one individual always gave the same type, and single spore colonies, if prepared from one of these fresh isolates, always gave colonies identical in appearance. In the fifty-five cases where *Calcarisporium* was obtained from more than one inoculum from each specimen, there was never any suggestion of more than one type of the endophyte occurring in one sporophore.

Calcarisporium has a relatively low growth rate compared with some parasitic moulds such as species of *Verticillium* found on agarics. At 23° C., the approximate optimum temperature, the rate of extension growth on agar was 1–2 mm./day. A similar rate of advance occurred in previously uninfected fruit-bodies of various ages inoculated in the laboratory.

Effect on host

The mould appeared to cause no symptoms in the growing fruit-bodies. This suggests that it can live endophytically in the host without causing any obvious disease. An alternative explanation might be that the fruit-bodies studied had only recently been invaded by *Calcarisporium* which, given time, would soon have produced disease symptoms.

There usually seemed to be a higher proportion of infected specimens among the older fruit-bodies. This suggests that the young infected ones grow up normally, and together with some later infected ones, form the infected part of the population of older fruit-bodies. Another explanation might be that they become obviously diseased soon after infection, and that the infected mature ones are the result of recent and rapid invasion by the *Calcarisporium*, and have not developed from infected young fruit-bodies. Little evidence could be obtained from the proportion of obviously diseased specimens found in nature, as only apparently healthy fruit-bodies were usually collected and no numerical records were kept of the numbers of diseased specimens.

The slow growth-rate of the endophyte supports the first hypothesis. Mature fruit-bodies, with caps of about 5 cm. diameter, have several times proved to contain it in all the inocula tried from various parts of the sporophore and seem to be systemically infected. The endophyte would take about 20 days to permeate an entire large mature sporophore at its normal growth rate even at the optimum temperature, if it can become systemic as a result of a single infection. Precise times of development of *Russula* fruit-bodies have not been recorded, but this time seems considerably longer than the time taken for a 'young' sporophore to develop to the 'young-mature' stage, or the latter to become 'mature'. However, if they were infected while very young there would probably be time to produce systemic infection by maturity. Therefore it seems that the large infected sporophores might either have developed from young infected ones, or have been entered at a number of different points by the endophyte, as this would enable it to permeate the entire fruit-body in a much shorter time. A study of the isolates indicates that the former hypothesis is probably correct and that a single infection is probably usual. Although the isolates were often distinguishable in appearance, and the types seemed to be randomly distributed, no indication of more than one type occurring in one fruit-body was obtained.

All this evidence strongly suggests that a single infection is sufficient to enable the endophyte to permeate the entire fruit-body. Probably infection takes place while the host is quite young, and it grows up normally containing the endophyte. Finally, when the host's vigour is reduced after maturity, or after being collected, the endophyte becomes apparent by producing its reproductive structures all over the surface of the host.

Discussion

Parasites of higher plants, such as *Epichloë* and members of the Ustilaginales, are known which can infect their hosts systemically, without producing disease symptoms for at least part of their association. However, there seem to be no previous records of a similar relationship between a fleshy fungus and its parasite.

This relationship is also interesting from the aspect of colonization of moribund organisms by soil scavengers. *Calcarisporium*, by entering the sporophores while they are still vigorous, gains an advantage over less specialized parasites when the agaric becomes old or damaged, and more vulnerable to attack from scavenging fungi. Then it produces its reproductive bodies in large numbers all over the dying host. Because of its much lower growth rate, it seems ill-adapted to colonize the host in competition with less specialized parasites such as *Verticillium*. These, however, seem unable to attack healthy growing fruit-bodies.

This is similar to the colonization of other dead and dying plant tissue in the soil, where root-inhabiting fungi are unable to colonize dead plant material in competition with obligate saprophytes, but can continue to live in the dead tissue if already established in it as a parasite. *Calcarisporium* could be considered as an 'ecologically obligate parasite' like some root-inhabiting fungi (Garrett, 1950). It resembles them in showing specialized parasitic ability combined with easy growth in culture and probably low competitive saprophytic ability.

Calcarisporium has previously been recorded as growing parasitically on various fungi, including Ascomycetes as well as agarics (Hughes, 1951). It seems to have developed a subtle parasitic arrangement with the two genera of agarics studied, and it would be very interesting to know more of its relationship with the other very varied fungi on which it has been recorded as growing openly. It would also be possible to grow the host and parasite in mixed cultures to study their relationship, which might be interesting from the nutritional and antibiotic aspects, as well as that of parasitism.

Thanks are due to Prof. C. T. Ingold, who supervised this work, and to Mr A. D. Greenwood and others for criticizing the manuscript. I also wish to thank Birkbeck College for the award of a Research Studentship, during the tenure of which most of the work was done.

REFERENCES

Garrett, S. D. (1950). Ecology of the root-inhabiting fungi. *Biol. Rev.* **25**, 220–254.
Hughes, S. J. (1951). Studies of Microfungi. IX. *Calcarisporium*, *Verticicladium* and *Hansfordia*. *Mycol. Pap.*, no. 43.
Pearson, A. A. (1948). The genus *Russula*. *Naturalist, Lond.*, pp. 85–108.
Pearson, A. A. (1950). The genus *Lactarius*. *Naturalist, Lond.*, pp. 81–99.

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THE ASEXUAL STAGE OF *APODACHLYA MINIMA*

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(With 1 Text-figure)

The zoosporangia of *Apodachlya minima* are described for the first time. A redescription of the oogonia and antheridia of the fungus is included.

Coker & Leitner (1938) described *Apodachlya minima* as a species distinguishable from known taxa principally on the basis of antheridial origin and oogonial size. The zoosporangia of *A. minima* were not observed by Coker & Leitner, nor could these structures be induced by nutritional or environmental variations.

Judging from the literature, *A. minima* is known only from the type locality. In December 1954, *A. minima* was collected on snake skin 'bait' from a soil sample taken in a ditch along Military Road, Rio Piedras, Puerto Rico. Both zoosporangia and oogonia were produced by the fungus. Inasmuch as the zoosporangia of *A. minima* have not, apparently, been previously observed, it seemed desirable to describe these structures, thereby completing the description of the species, and ensuring unquestionably its position in the genus.

The fungus was isolated by placing a single undischarged zoosporangium in a drop of sterile, charcoal-filtered distilled water on the surface of a small piece of snake skin floating in a Petri plate. Thirty-six hours later the substratum was forced below the surface of the culture water, and the developing colony incubated at 25° C. Numerous zoosporangia and oogonia were produced, but the latter structures were generally sessile on the substratum. Short oogonial stalks were occasionally observed, but their origin could not be clearly distinguished.

Halves of sterilized hempseed were placed on infested snake skin, and in 3–5 days the fungus produced colonies 1–1·5 cm. in diameter on the new substratum. Laterally attached, short-stalked oogonia, or, rarely, terminally arranged oogonia were produced on the principal hyphae. A few zoosporangia developed very near the substrate surface. Subsequent to the initiation of oogonia, the zoosporangia were observable only if the hyphae were dissected away from the hempseed, and observations made near the hyphal bases. The rather obscure nature of the asexual structures in colonies propagated on hempseed suggests a reason for Coker & Leitner's failure to observe them. The following description of the asexual stage of *Apodachlya minima* is compiled principally from the characteristics of the

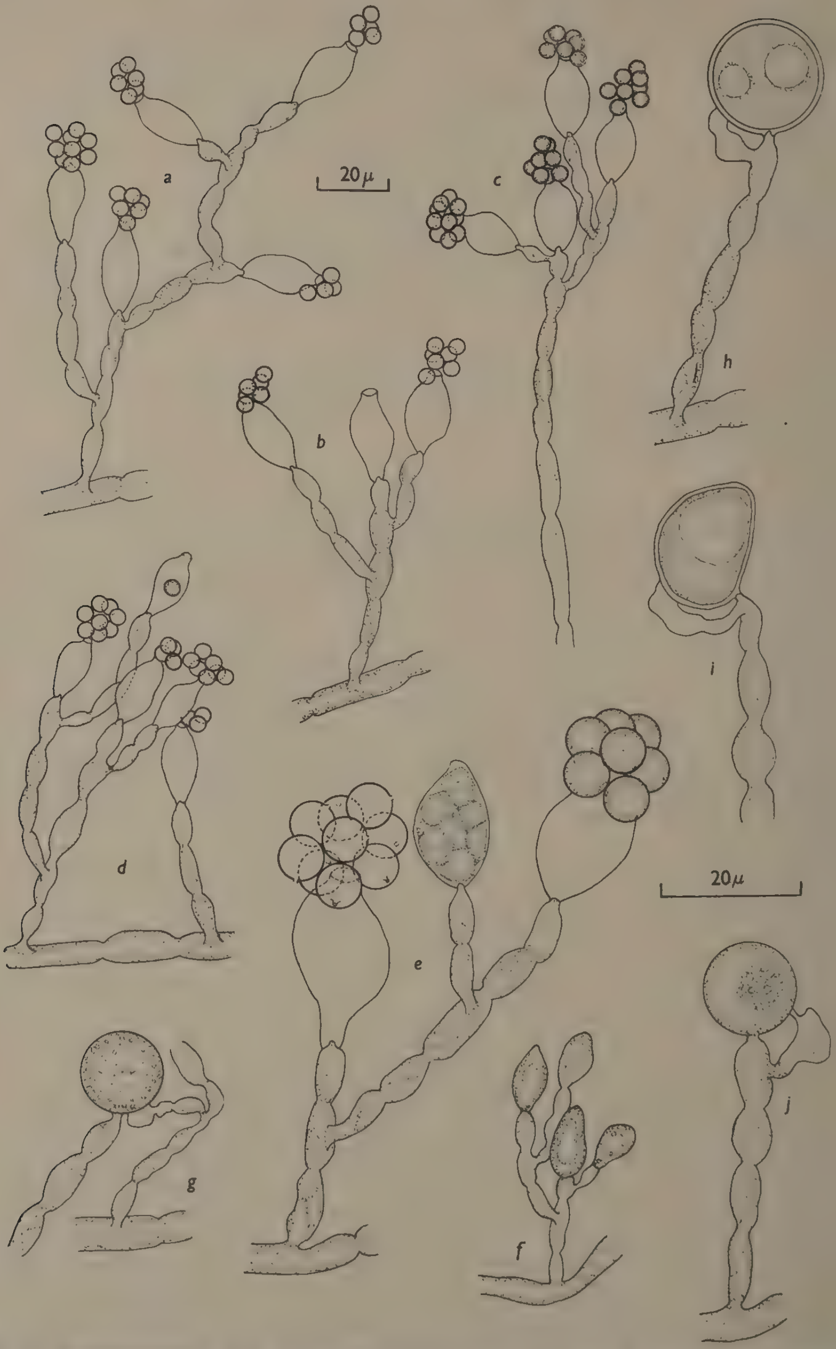

Fig. 1. *Apodachlya minima.* *a*, *b*, glomerulate zoosporangia; *c*, cluster of terminal zoosporangia; *d*, glomerulate zoosporangia, and a single laterally attached zoosporangium; *e*, stages in development and discharge of zoospores; *f*, immature zoosporangia; *g*, immature oogonium with attached diclinous (?) antheridium; *h*, *i*, oogonia with oospores and suboogonial antheridia; *j*, immature oogonium with a functional suboogonial antheridium.

zoosporangia as they appeared on snake skin; the sexual stage is described primarily from hempseed cultures.

The zoosporangia of *Apodachlya minima* are variable in shape, but generally suggest those of *A. pyrifera* var. *pyrifera* Zopf (1888). Asymmetrical, ovoid or pyriform zoosporangia are the most commonly occuring types (Fig. 1 *a–d*). The size of discharged zoosporangia, 17·6–26·2 μ long, 12·8–17·6 μ in diameter, also corresponds rather closely to that of Zopf's species. The arrangement of zoosporangia in *A. minima*, however, seems to be quite different from that of any other *Apodachlya*, since these are generally produced in glomeruli arising from a single lateral branch (Fig. 1 *a*). Infrequently, the zoosporangia are terminal, but in such instances they are clustered (Fig. 1 *c*). Only rarely are the asexual structures produced singly on a short lateral branch (Fig. 1 *d*, in part). From the standpoint of shape and size, therefore, the zoosporangia of *A. minima* do not differ significantly from those of other taxa in the genus, except for *A. brachynema* var. *major*. The zoosporangial glomeruli, however, seem particularly characteristic.

Very few zoospores are produced, and in common with other members of the genus, these generally encyst after emergence (Fig. 1 *c*) in an achlyoid cluster at the zoosporangial orifice. Zoospores emerge from the cysts as laterally biflagellate, isocont (?) planonts, leaving clusters of cyst walls at the zoosporangial apex (Fig. 1 *a*). Flagellation of the primary zoospores was not observed. In the encysted stage, the zoospores are 6·5–8·0 μ in diameter.

Coker & Leitner pointed out that the oogonia of *A. minima* vary in form from spherical to bilobate. Such variations were observed in the Puerto Rico material, particularly in colonies propagated on snake skin. The spherical oogonia range in diameter from 14 to 20 μ, hence they are slightly larger than those reported by Coker & Leitner (12–16 μ). The oospores contain very finely granular, nearly hyaline ooplasm surrounding one or two eccentric oil globules (Fig. 1 *h*, *i*). Antheridia arise as short branches from the suboogonial cells (Fig. 1 *j*), quite similar to the origin described by Coker & Leitner. Antheridial branches suggestive of a diclinous origin (Fig. 1 *g*) were observed very rarely.

Coker & Leitner (1938, p. 313) stated in a footnote to their description of *Apodachlya minima* that some '. . . mature oogonia [oospores, presumably] have the same appearance as shown by von Minden . . .' for *A. punctata* (von Minden, 1912). From the writer's observations on the oospores of *A. minima* in comparison with the oospores of *A. punctata* (also collected from Puerto Rico soil) it is conclusive that this resemblance is entirely superficial. The oospores of *A. punctata*, as Sparrow (1943, p. 570) pointed out, are unquestionably punctate, and do not appear to be so because of oil droplet arrangement, as Coker & Leitner believed on the basis of their observations of *A. minima*.

Apodachlya minima occupies a position in the genus concomitant with that of *A. brachynema* var. *brachynema* and *A. pyrifera* var. *pyrifera*. These taxa produce zoosporangia singly or in clusters, and not in basipetalous succession as in *A. seriata*.

The author is indebted to Miss Carmen Rossy-Valderrama for supplying the soil samples, and to Mr W. H. Wheeler, Plant Quarantine Branch, United States Department of Agriculture, for authorizing and expediting clearance of the samples into the United States.

REFERENCES

COKER, W. C. & LEITNER, JANE (1938). New species of *Achlya* and *Apodachlya*. *J. Elisha Mitchell Sci. Soc.* **54**, 311–318.

MINDEN, M. VON (1912). Saprolegnineae. *Kryptogamenfl. Mark Brandenburg*, **5** (4), 497–608. 1915.

SPARROW, F. K., Jr. (1943). *Aquatic Phycomycetes exclusive of the Saprolegniaceae and* Pythium. Ann Arbor: University of Michigan Press.

ZOPF, W. (1888). Zur Kenntniss der Infektions-Krankheiten niederer Thiere und Pflanzen. *Nova Acta Acad. Leop.-Carol.* **52**, 313–376.

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EMERICELLOPSIS MINIMA SP.NOV. AND *WESTERDYKELLA ORNATA* GEN.NOV., SP.NOV.

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(With Plate 15 and 2 Text-figures)

Two new fungi, isolated from East African mangrove mud, are described and figured: *Emericellopsis minima* sp.nov. and *Westerdykella ornata* gen.nov., sp.nov. Both species belong to the Eurotiaceae. The related fungus *Peyronellula mirabilis* Malan has been transferred to the genus *Emericellopsis* van Beyma.

The two fungi described in this paper were encountered in the course of an investigation of fungi occurring in the mangrove mud of the island of Inhaca, Mozambique, East Africa. Both fungi were isolated by Mr H. J. Swart, University of the Witwatersrand, Johannesburg, and were sent to the Centraal Bureau voor Schimmelcultures (C.B.S.), Baarn for identification. Living cultures of the two species are maintained at the C.B.S. Dried cultures will be sent to the Rijksherbarium, Leiden, Netherlands, to the Herbarium of the Royal Botanic Gardens, Kew, and to the Herbarium of the Commonwealth Mycological Institute, Kew, England.

Emericellopsis minima sp.nov. (Text-fig. 1 *a*–*g*)

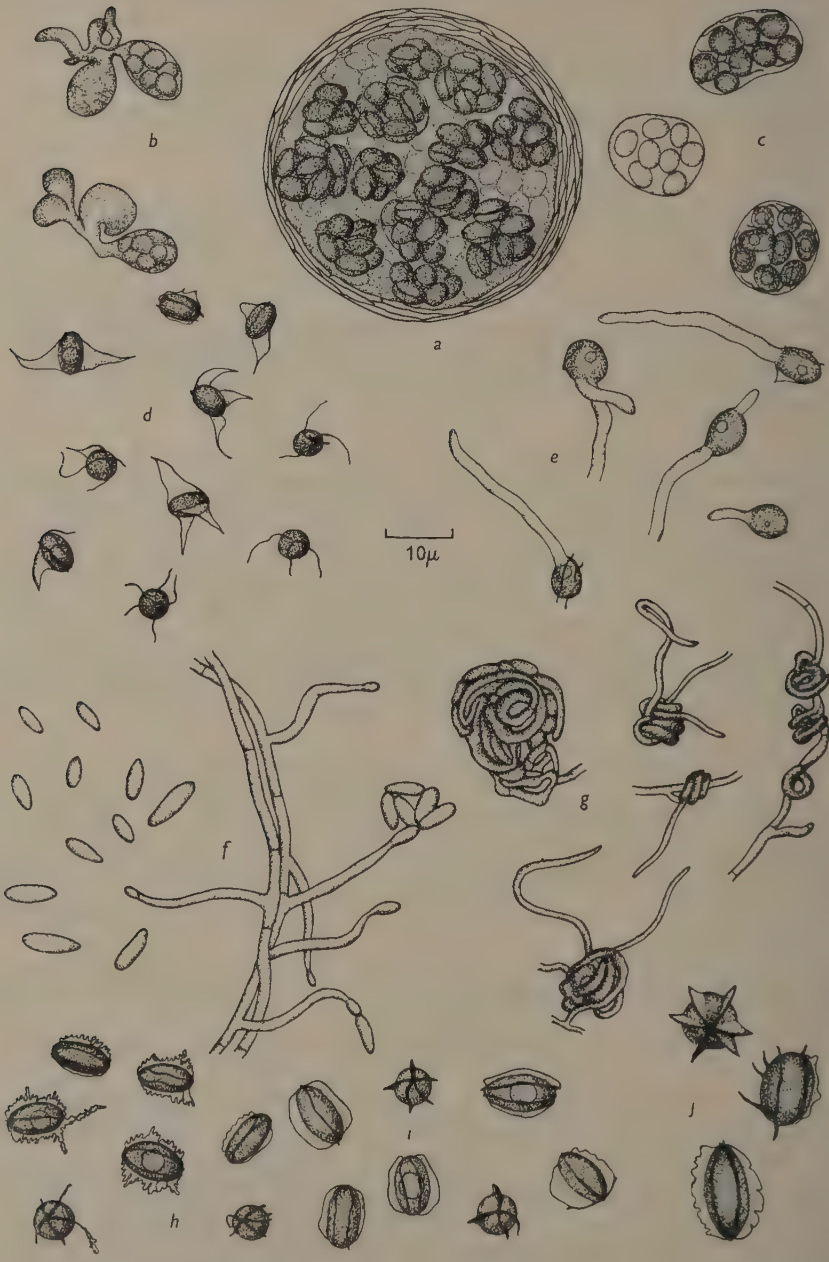
Perithecia globosa, glabra, brunnea, plerumque clausa, interdum poro pertusa, 90–300μ diam. Paries peritheciorum e cellularum stratis multis compositus, 7–15μ crassus; cellulae pellucide pallide-brunneae. Asci numerosi, globosi vel subglobosi, sessiles, 8-spori, 12–16 × 10–12μ, evanescentes. Ascosporae subglobosae-ellipsoideae, continuae, diu hyalinae, postea olivaceo-brunneae, 3–5 appendicibus longitudinalis, 5–6 × 3·5–4μ.

Stat. conid.: *Cephalosporium.*

Conidiophorae hyalinae, non ramosae, 20–30 × 2–2·5μ. Conidia ellipsoidea, hyalina, continua, 4–10 × 2–3·5μ. Mycelium hyalinum, septatum et ramosum, ex hyphis 1–3μ diam.

Hab. in vitro ex terra: Africa orientalis, Mozambique, insula Inhaca, leg. H. J. Swart, 1953.

Colonies on oatmeal agar in Petri dishes grow fairly rapidly, attaining a diameter of 3 cm. in 1 week at room temperature. The submerged mycelium, forming a solid pellicle, is Pale Salmon to Salmon coloured (Ridgway, 1912). The fungus readily produces perithecia on most media, especially on oatmeal or cornmeal agar. The globose, glabrous, brown to black perithecia, 90–300μ in diameter, are found not only on the surface, but also submerged in the upper layer of the culture medium. They are mostly astomous, producing sometimes at maturity a porus. The perithecium has a stout wall, 7–15μ thick and composed of about five layers of pale ellow-brown cells. The dark ascospores give the fruit-bodies a dark brown



Text-fig. 1. *Emericellopsis minima*. *a*, transverse section through a nearly ripe perithecium; *b*, ascogenous hyphae with young sessile asci; *c*, young and ripe asci; *d*, ascospores showing longitudinal appendages; *e*, germinating ascospores; *f*, conidial stage; *g*, perithecial initials. *Emericellopsis terricola*: *h*, ascospores. *i*, *Emericellopsis terricola* var. *glabra*: ascospores. *j*, *Emericellopsis mirabilis*: ascospores.

appearance (Text-fig. 1 *a*). The evanescent asci (Text-fig. 1 *c*), containing eight ascospores are subglobose, 12–16 × 10–12 μ. The ascospores (Text-fig. 1 *d*) are characterized by two to five hyaline, longitudinal wing-like appendages, which come together at the poles. The wings are mostly somewhat triangular, but in older spores they disintegrate and become very irregular in shape. When focusing the poles of the ascospores, the wings appear as whip-like appendages, 3·5–6 μ in length. The young ascospores are hyaline, turning olive brown at maturity. They are continuous, subglobose to elliptical, 5–6 × 3·5–4 μ, often containing one large drop of oil. No germpore has been observed. The germinating ascospores swell considerably, producing one or two germtubes in 24 hr. at 25° C. (Text-fig. 1 *e*).

The conidial stage of the fungus shows the characteristics of the genus *Cephalosporium* Corda (Text-fig. 1 *f*). The conidial slime heads are about 10 μ in diameter. The length of the conidiophore ranges from 20 to 30 μ, its diameter is 2–2·5 μ. The elliptical, hyaline and continuous conidia measure 4–10 × 2–3·5 μ.

Mycelium and conidiophores are hyaline. The diameter of the hyphae is 1–3 μ. Frequently anastomoses between two hyphae are found. The perithecium develops from a hyphal coil (Text-fig. 1 *g*). No differentiated antheridial cell could be distinguished and no fusion has been observed between coiling hyphae. From the coil a nearly spherical structure originates. Microtome sections of young perithecia show the formation of the peridial wall-cells. Within these wall-cells a mass of hyaline pseudoparenchymatous tissue is formed, in the centre of which the ascogenous hyphae can be found. The sessile asci are abundantly formed as side branches from ascogenous hyphae (Text-fig. 1 *b*), and they become interpolated between the cells of the ground tissue (Text-fig. 1 *a*). Finally, ground tissue, ascogenous hyphae and asci disappear and the ripe perithecium is completely filled with the brown ascospores.

On account of its dark-coloured and winged ascospores, the fungus under consideration can best be placed in the genus *Emericellopsis* van Beyma (1939–40). The present fungus, however, differs from the described species of *Emericellopsis* in the size of the ascospores and in the shape of the appendages (Text-figs. 1 *d* and 1 *h–j*):

	Size of the ascospores (μ)
E. minima sp.nov.	5–6 × 3·5–4
E. terricola van Beyma	8–9·5 × 4·2–5·1
E. terricola var. *glabra* van Beyma	9–10·5 × 5–5·8
E. mirabilis (Malan) comb.nov.	10–14 × 5–6·5

It seems best, therefore, to consider the present fungus as a new species and the name *Emericellopsis minima* is proposed.

Emericellopsis mirabilis (Malan) comb.nov.

syn. *Peyronellula mirabilis* Malan, *Mycopathologia et Mycologia applicata*, **6**, 165, 1952.

The monotypic genus *Peyronellula* was based by Malan on the fungus *P. mirabilis*. Examination of the type strain made it clear that *Peyronellula* must be considered as a synonym of *Emericellopsis*. This is because of the structure of its perithecia, its brown ascospores, provided with three to six longitudinal crests and its *Cephalosporium* conidial stage.

Westerdykella gen.nov.

Perithecia globosa, astomata, atrobrunnea; pariete membranacea, brunneo-nigra, ex uno strato cellularum composita. Asci numerosi, ellipsoidei, pedunculati, membranis tenerrimis evanescentibus, multa sporidia continentes. Sporae ex una cellula constantes, globosae ellipsoideae, brunnae, ligamentibus spiralibus ornatae; non porus germinatus.

Perithecia globose, astomous, black. Perithecium wall membranaceous, consisting of one layer of brown to black thick-walled cells. Asci numerous, subglobose to elliptical, stalked, many-spored, evanescent. Ascospores globose to subglobose, continuous, brown, provided with spiral bands. No germ pores.

Westerdykella ornata sp.nov. (Pl. 15; Text-fig. 2)

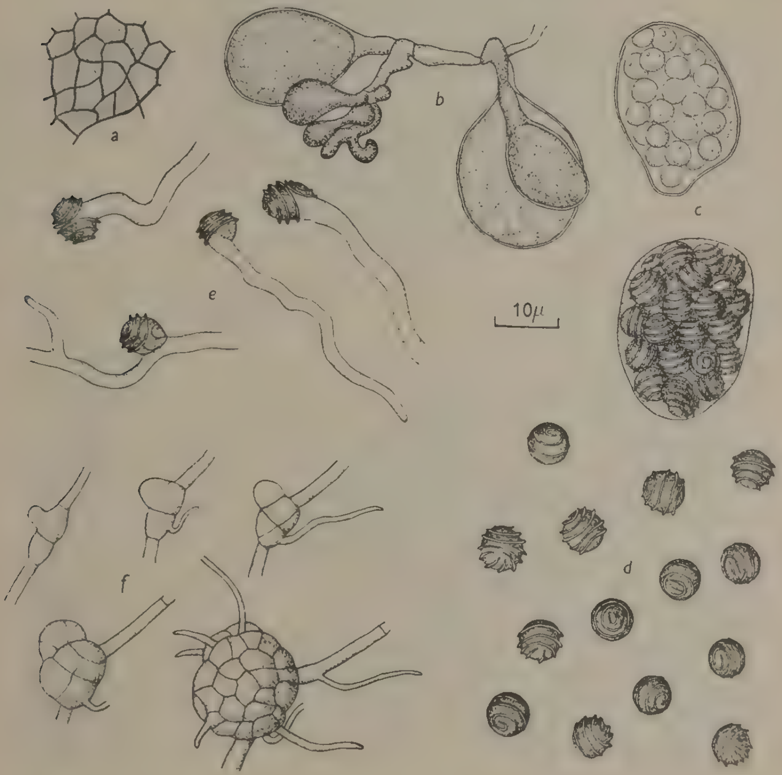
Perithecia globosa, clausa, glabra, atrobrunnea, 100–300 μ diam., pariete ex uno strato cellularum polygonarum, 4–6 μ diam., crasso membrano brunnearum. Asci nascentes ex hyphis hyalinis, 2–3 μ diam., evanescentibus, numerosi, ellipsoidei, pedunculati, 32-spori, 25–32 × 16–22 μ, mucosi. Ascosporae continuae, globosae, brunneae, ligamentis 4–5 spiris ornatae, 6·2–7 × 6–6·8 μ. Mycelium hyalinum, granulis flavorufis, septatum, ramosum, ex hyphis 1–3 μ diam. Conidia non formata.

Hab. in vitro ex terra: Africa orientalis, Mozambique, insula Inhaca, leg. H. J. Swart, 1953.

Colonies on oatmeal agar in Petri dishes (Pl. 1, fig. 1) grow slowly, attaining a diameter of about 4·5 cm. in 2 weeks at 25° C. The submerged mycelium is Orange Buff, Capucine Yellow or Orange (Ridgway, 1912), some white and Orange Buff aerial mycelium can be produced as sterile overgrowth. In older cultures the many black perithecia give the cultures a dark appearance. The colour and the texture of the cultures vary with the density of the perithecia and the presence and the colour of the overgrowth. In Petri dishes the cultures frequently show a tendency to sectoring. On malt agar the aerial mycelium is white to Flesh Colour, the centre is dark grey, no perithecia are found.

On oatmeal agar the cleistocarpous perithecia are produced on the surface and in the upper layer of the culture medium. They are globose, brown to black, glabrous, 100–300 μ in diameter. The wall of the mature perithecium is made up of only one layer of polygonal, dark brown, thick-walled cells, about 5 μ in diameter (Text-fig. 2*a*). The centre of the perithecium consists of a thin-walled ground tissue in which numerous asci are embedded (Pl. 15, fig. 2). The subglobose to elliptical asci (Text-fig. 2*c*), each containing about 32 ascospores, measure 25–32 × 16–22 μ. The ripe ascospores are globose, continuous, brown, 6·2–7 × 6–6·8 μ and are ornated by irregular spiral bands, which occur in four to five coils (Pl. 15, fig. 3; Text-fig. 2*d*). No germpore has been observed. The ascospores germinate readily; in 24 hr. at 25° C. one germ tube is produced (Text-fig. 2*e*). No conidial stage has been observed.

The mycelium is hyaline. In the hyphae many yellow to orange-coloured granulae may occur. The diameter of the hyphae is 2–3μ. The perithecium originates from intercalary cells of the hyphae, not from a hyphal coil, as occurs in most Eurotiaceae. These intercalary cells swell considerably and stain deeply with cotton blue; they divide and produce many daughter-cells, thus forming a solid spherical body (Text-fig. 2*f*). These perithecial initials can already be found in 1-week-old cultures.



Text-fig. 2. *Westerdykella ornata*. *a*, polygonal peridial cells; *b*, ascogenous hyphae with young, stalked asci; *c*, young and ripe asci; *d*, ascospores showing irregular spiral bands; *e*, germinating ascospores; *f*, different stages in the development of a perithecium, studied in a hanging-drop culture during 3 days.

Microtome sections of young perithecia show a hyaline pseudo-parenchymatous ground tissue, surrounded by one layer of thick-walled brown peridial cells. In the centre of the pseudo-parenchymatous tissue the ascogenous hyphae develop. The stalked asci are produced as side branches from ascogenous hyphae (Text-fig. 2*b*). Ultimately ground tissue, ascogenous hyphae and asci disappear.

No description of this fungus could be found, nor a genus in which it could be placed. It is therefore proposed to make the present fungus the type of a new genus and the name of *Westerdykella ornata* is suggested. The genus is named after Prof. Dr Joha. Westerdijk, director of the Centraal Bureau voor Schimmelcultures.

The genus *Westerdykella*, which belongs in the Phaeosporeae of the Eurotiaceae (Clements and Shear, 1931), should be placed near the genus *Pseudeurotium* van Beyma (van Beyma, 1937; Stolk, 1955), from which it differs in the character of the ascospore wall.

REFERENCES

van Beyma thoe Kingma, F. H. (1937). Beschreibung einiger neuer Pilzarten aus dem 'Centraalbureau voor Schimmelcultures' Baarn (Holland), IV. Mitteilung. *Zbl. Bakt.* (2. *Abt.*), **96**, 411–432.

van Beyma thoe Kingma, F. H. (1939–40). Beschreibung einiger neuer Pilzarten aus dem 'Centraalbureau voor Schimmelcultures', Baarn (Nederland), VI. Mitteilung. *Leeuwenhoek ned. Tijdschr.* **6**, 263–290.

Clements, F. E. & Shear, C. L. (1931). *The genera of fungi*, pp. 247–248. New York.

Malan, C. E. (1952). Sopra un interessante plectomicete umicolo nuovo per la scienza: *Peyronellula mirabilis* n.g. et n.sp. *Mycopathologia*, **6**, 164–175.

Ridgway, R. (1912). *Color standards and color nomenclature.* Washington, D.C.

Stolk, A. C. (1955). The genera *Anixiopsis* Hansen and *Pseudeurotium* van Beyma. *Leeuwenhoek ned. Tijdschr.* **21**, 65–79.

EXPLANATION OF PLATE

Westerdykella ornata gen. et sp.nov.

Fig. 1. Culture on oatmeal agar in Petri dish showing sectors.
Fig. 2. Transverse section through a perithecium showing many-spored asci. × 1000.
Fig. 3. Ascospores. × 1000.

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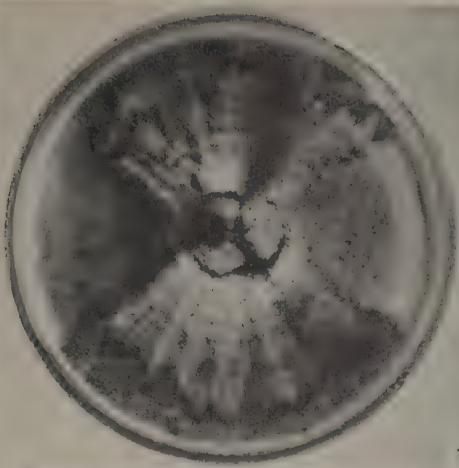

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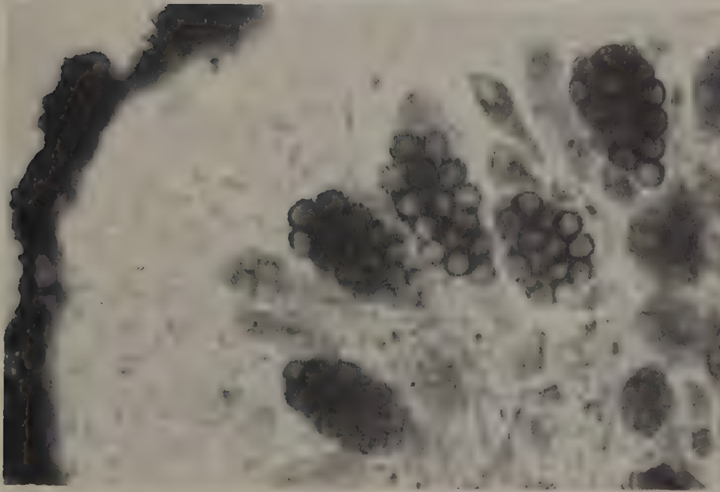

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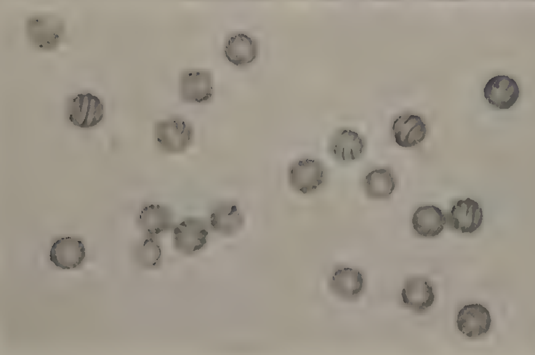

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Trans. Brit. mycol. Soc. **38** (4), 425–430 (1955).

ANNOTATED LIST OF BRITISH AQUATIC CHYTRIDS (SUPPLEMENT I)

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This list is the first supplement to an Annotated List of British aquatic chytrids (Canter, 1953).

The previous list of British aquatic Chytrids, Canter (1953), concerns those species published up to December 1952. This first supplement deals with two papers omitted from the original list, Karling (1946), Ingold (1952) and new papers by Roberts (1953), Canter & Lund (1953) and Canter (1954). As before, an asterisk (*) denotes that the fungus is figured in the paper concerned. All the species are parasitic unless otherwise stated. The localities of lakes and smaller bodies of water not mentioned in the previous paper are to be found on p. 429. The imperfectly known chytrids occurring on diatoms mentioned by Canter and Lund (1953) are listed on p. 428 and are not included in the substratum index.

Nomenclatural changes

Karling (1953) merges the genus *Micromyces* with *Synchytrium* and renames the species accordingly.

Knudson (1952) renames the diatom *Tabellaria fenestrata* (Lyngb.) Kütz var. *asterionelloides* Grun.; it becomes *Tabellaria flocculosa* (Roth) Kütz. var. *asterionelloides* (Grun.) Knudson.

Lund (1954) renames the diatom *Melosira italica* (Ehr.) Kütz.; it becomes *Melosira italica* subsp. *subarctica* O. Müll.

OLPIDIACEAE

Pleotrachelus wildermani Petersen

Ingold (1952*): in rhizoids of *Funaria hygrometrica* Hedw., Leicester (coll. Dr W. Tutin).

The Leicester material agrees fairly well with that described by Petersen (1910) from Denmark, but for the fact that the sporangia had only one exit tube (cf. two figured by Petersen).

SYNCHYTRIACEAE

Micromycopsis oedogonii Roberts

Roberts (1953*): in *Oedogonium* sp., Bolder Mere, Wisley, Surrey. Type material deposited at the Commonwealth Mycological Institute, Kew (Herb. I.M.I. 50464).

RENAMED SPECIES

Karling (1953) merged the genus *Micromyces* with *Synchytrium*. The species recorded by Canter (1953, p. 282) are renamed *Synchytrium laevis* (Canter) Karling, *S. petersenii* (Scherffel) Karling and *S. zygogonii* (Dang.) Karling. *S. laevis* and *S. zygogonii* are included in the subgenus, *Micro synchytrium*. It is uncertain as to whether *S. petersenii* belongs in this subgenus until germination of the resting spore is observed (see Karling, 1953, p. 285).

PHLYCTIDIACEAE

Rhizophidium difficile Canter

Canter (1954*): on *Staurastrum jaculiferum* W. West, Windermere, north and south basins (type locality): and on *Arthrodesmus* sp., Bassenthwaite Lake.

?Rhizophidium fusus (Zopf) Fischer

Canter & Lund (1953*): on preserved material of *Melosira granulata* (Ehr.) Ralfs, Lough Oughter.

Rhizophidium keratinophilum Karling

Karling (1946*): saprophytic on keratinized material from soil, Dublin, Eire.

Rhizophidium oblongum Canter

Canter (1954*): on *Dinobryon divergens* Imhof, Blelham Tarn (type locality), Windermere (north and south basins), Derwentwater, Coniston Water, Elterwater, Grasmere, Rydal Water, Esthwaite Water, Loughrigg Tarn and in Grisedale Tarn and Red Tarn in the Helvellyn Range, Westmorland, the English Lake District; and on *D. stipitatum* Imhof, Grasmere and Elterwater.

Rhizophidium planktonicum Canter

Canter & Lund (1953): on *Asterionella formosa* Hass., Loch Uanagan.

It is now known that the sporangia with wide lateral dehiscence openings figured as this species in (Canter & Lund, 1948, fig. 10B) do not belong here but to *Chytriomyces* sp. (see p. 427).

Rhizophidium uniguttulum Canter

Canter (1954*): on *Gemellicystis neglecta* (Teil.) Skuja, Windermere, north and south basins (type locality), Blelham Tarn, Esthwaite Water, Ullswater, Coniston Water and Bassenthwaite Lake.

Rhizosiphon akinetum Canter

Canter (1954*): on akinetes of *Anabaena affinis* Lemm. var. *intermedia* Griffiths, Blake Mere (type locality), Kettle Mere, and White Mere, Cheshire. The description of this fungus is based on preserved material collected by the late Dr B. M. Griffiths. Griffiths (1925) records the presence of this fungus but no details are given.

Septosperma anomala (Couch) Whiffen

Canter & Lund (1953*): on sporangia resembling those of *Chytriomyces* sp., Sunbiggin Tarn; on 'species 3' (Canter & Lund (1953), p. 20*)†, Swithland Reservoir, Leic.

Septosperma sp.

Canter & Lund (1953*): saprophytic on *Melosira italica* (Ehr.) Kütz., Blelham Tarn, Esthwaite Water, Windermere (south basin), Haweswater, Loweswater and Ullswater.

CHYTRIDIACEAE

Chytridium versatile Scherffel

Canter & Lund (1953): on *Tabellaria fenestrata* (Lyngb.) Kütz. var. *asterionelloides* Grun., Ullswater.

Zygorhizidium melosirae Canter

Canter & Lund (1953): on *Melosira italica* (Ehr.) Kütz, Swithland Reservoir, Leic.

Zygorhizidium parallelosede Canter

Canter (1954*): on *Ankistrodesmus* sp., Windermere north and south basins (type locality), Blelham Tarn, Esthwaite Water, Crummock Water, Wastwater, Ullswater, High Borrans Reservoir, near Windermere Town, Westmorland and St Johns Loch; and on *Elakatothrix gelatinosa* Wille, Ennerdale Water and Windermere (north and south basins).

Zygorhizidium planktonicum Canter

Canter & Lund (1953*): on *Asterionella formosa* Hass., Malham Tarn, Loughs Derg and Talt. The sporangial stage alone has been found in Lough Oughter, and Loch Tay.

Chytriomyces sp. Canter

Canter & Lund (1953*): on *Asterionella formosa* Hass., Blelham Tarn, Windermere (north and south basins), Malham Tarn, and Loch Lochy.

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† See Canter & Lund (1953), p. 22, bottom paragraph, which should read: 'The hyperparasite *S. anomala* (Couch) Whiffen (fig. 2L–O) was frequently observed in the material of *Fragilaria crotonensis* except that from Lough Erne, Barn Elms Reservoir, Rostherne Mere and the English Lake District though it does occur in the latter on *Chytriomyces tabellariae* Canter (1949).'

There is no doubt that the sporangia which have dehisced laterally in (Canter & Lund (1948) fig. 10B) belong to this species and not to *Rhizophidium planktonicum.* Similar sporangia are known from Bassenthwaite Lake, Sunbiggin Tarn and Lough Erne.

Canter & Lund (1953) record several chytrids on planktonic algae which did not occur in sufficient quantity to permit a definite identification. For convenience, the species are divided into the two categories listed below:

A. *Species which are figured and discussed*

(1) (P. 15, 'species 4'*): on *Asterionella formosa* Hass., in the shallow tarn at Tarns, near Silloth, Cumberland. This species may be *Chytridium versatile* Scherffel.

(2) (P. 17, 'species 5'*): on *Asterionella formosa* Hass., in the shallow tarn at Tarns, near Silloth, Cumberland.

(3) (P. 20, 'species 3'*): on *Fragilaria crotonensis* (Edw.) Kitton, Rostherne Mere, Barn Elms Reservoir, Swithland Reservoir and Lough Erne.

(4) (P. 28, ?*Rhizophidium* sp.*): on *Tabellaria fenestrata* (Lyngb.) Kütz. var. *asterionelloides* Grun., and the *T. flocculosa* complex, Esthwaite Water, Ullswater, Windermere (north and south basins) and Bigland Tarn.

(5) (P. 31*): on *Tabellaria fenestrata* (Lyngb.) Kütz. var. *asterionelloides* Grun., Windermere (south basin) and on the *T. flocculosa* complex, Ullswater, Blelham Tarn and Esthwaite Water. The sporangium of this fungus resembles an operculate form of *Rhizidiopsis emmanuelensis* Sparrow.

(6) (P. 31*): on *Rhizosolenia eriensis* H. L. Smith, Blelham Tarn, Windermere (north and south basin), Ullswater, Crummock Water, Ennerdale Water, Loweswater, Coniston Water, Haweswater, Bassenthwaite Lake. Canter (unpublished): Derwentwater and Loughrigg Tarn.

(7) (P. 32*): on *Stephanodiscus astraea* (Ehr.) Grun. var. *minatula* (Kütz.) Grun., Windermere (north and south basins), Derwentwater and Ullswater. This fungus may be *Zygorhizidium planktonicum* Canter.

B. *Species for which no details are given*

(P. 17): on *Asterionella formosa* Hass., Derwentwater, Thirlmere, Elterwater, Grasmere, Bigland Tarn, Middlerigg Tarn, Overwater, Swithland Reservoir, Loughs Cullin, Erne and Glencar.

(P. 27): on *Melosira* spp., Lough Erne and Llyn Maelog.

(P. 31): on *Cyclotella* spp., Windermere (north and south basins), Esthwaite Water, Blelham Tarn, Ullswater, Haweswater and Crummock Water: on *C. comta* (Ehr.) Kütz., Swithland Reservoir. (A spherical epibiotic chytrid.)

(P. 32): on *Cyclotella praetermissa* Lund, Haweswater. (A polyphagoid chytrid.)

FURTHER RECORDS OF LAKES AND SMALLER BODIES OF WATER CONTAINING CHYTRIDS OCCURRING ON PLANKTONIC ALGAE

ENGLAND
The Lake District
Ennerdale Water
Grisedale Tarn (Helvellyn)
High Borrons Reservoir
Middlerigg Tarn
Overwater
Red Tarn (Helvellyn)

Cheshire
Blake Mere
Kettle Mere
White Mere

EIRE
Mayo
†Lough Cullin

SCOTLAND
Inverness-shire
Loch Lochy
St Johns Loch
Loch Uanagan

Perthshire
Loch Tay

WALES
Anglesey
Llyn Maelog

LIST OF SUBSTRATA

ALGAE

CHLOROPHYCEAE
Chlorococcales
Ankistrodesmus sp.: Zygorhizidium parallelosede.
Elakatothrix gelatinosa: Zygorhizidium parallelosede.
Gemellicystis neglecta: Rhizophidium uniguttulum.
Oedogoniales
Oedogonium sp.: Micromycopsis oedogonii.
Conjugales
Arthrodesmus sp.: Rhizophidium difficile.
Staurastrum jaculiferum: Rhizophidium difficile.

CHRYSOPHYCEAE
Dinobryon divergens: Rhizophidium oblongum.
Dinobryon stipitatum: Rhizophidium oblongum.

BACILLARIOPHYCEAE
Asterionella formosa: Chytriomyces sp., Zygorhizidium planktonicum.
Melosira granulata: (?) Rhizophidium fusus.
Melosira italica subsp. *subarctica:* Septosperma sp., Zygorhizidium melosirae.
Tabellaria flocculosa var. *asterionelloides:* Chytridium versatile.

CYANOPHYCEAE
Anabaena affinis var. *intermedia:* Rhizosiphon akinetum.

FUNGI

?*Chytriomyces sp.:* Septosperma anomala.

MUSCI

Funaria hygrometrica (*rhizoids*)*:* Pleotrachelus wildermani.

DEBRIS

Keratinized material: Rhizophidium keratinophilum.

† Erroneously placed in Scotland by Canter & Lund (1953), p. 36.

REFERENCES

Canter, H. M. (1953). Annotated list of British aquatic chytrids. *Trans. Brit. mycol. Soc.* **36**, 278–303.

Canter, H. M. (1954). Fungal parasites of the phytoplankton. III. *Trans. Brit. mycol. Soc.* **37**, 111–133.

Canter, H. M. & Lund, J. W. G. (1948). Studies on plankton parasites. I. Fluctuations in the numbers of *Asterionella formosa* Hass., in relation to fungal epidemics. *New Phytol.* **47**, 238–261.

Canter, H. M. & Lund, J. W. G. (1953). Studies on plankton parasites. II. The parasitism of diatoms with special reference to lakes in the English Lake District. *Trans. Brit. mycol. Soc.* **36**, 13–37.

Griffiths, B. M. (1925). Studies in the phytoplankton of the lowland waters of Great Britain, no. III. The phytoplankton of Shropshire, Cheshire, and Staffordshire. *J. Linn. Soc. (Bot.)*, **47**, 75–98.

Ingold, C. T. (1952). *Funaria* rhizoids infected with *Pleotrachelus wildermani*. *Trans. Brit. bryol. Soc.* **2**, 53–54.

Karling, J. S. (1946). Keratinophilic Chytrids. I. *Rhizophydium keratinophilum* n.sp., a saprophyte isolated on human hair, and its parasite, *Phlyctidium mycetophagum* n.sp. *Amer. J. Bot.* **33**, 751–757.

Karling, J. S. (1953). *Micromyces* and *Synchytrium*. *Mycologia*, **45**, 276–287.

Knudson, B. M. (1952). The diatom genus *Tabellaria*. I. Taxonomy and morphology. *Ann. Bot., Lond.*, N.S., **26**, 421–440.

Lund, J. W. G. (1954). The seasonal cycle of the plankton diatom, *Melosira italica* (Ehr.) Kütz. subsp. *subarctica* O. Müll. *J. Ecol.* **42**, 151–179.

Petersen, H. E. (1910). An account of Danish freshwater Phycomycetes, with biological and systematical remarks. *Ann. mycol., Berl.*, **8**, 494–560.

Roberts, M. (1953). *Micromycopsis oedogonii* sp.nov. *Trans. Brit. mycol. Soc.* **36**, 320–323.

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Trans. Brit. mycol. Soc. **38** (4), 431–434 (1955).

STYLOPAGE ARAEA DRECHSLER VAR. *MAGNA* VAR.NOV.

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(With 2 Text-figures)

A new variety of *Stylopage araea* Drechsler which captures amoebae and produces larger conidia than those of the type variety is described from England.

Stylopage araea Drechsler var. **magna** var.nov. (Figs. 1, 2)

A typo differt conidia 12·5–37·5 μ (saepius 22–33 μ) longa, 5·5–12 μ (saepius 7–11 μ) crassis; hyphis fertilibus ad 150 μ altis. Hab. in excreta animalis, Westley Heights, Langdon Hills, Essex, Anglia. January 1955.

This fungus was first obtained from cow dung collected at Westley Heights, Langdon Hills, Essex, on 27 April 1952, and placed on sterile maize-meal agar plates 2 days later. The fungus was observed capturing amoebae 2 weeks later. Very little material was available at the time, but measurements indicated that it differed from any of the described species of *Stylopage*, and comparison of drawings and measurements made in 1952 with the material obtained recently indicate that it was the same fungus that we are describing here.

We obtained a fair amount of material recently from two sources: (*a*) Pieces of cow dung collected from Westley Heights, Langdon Hills, Essex, on 23 November 1954, were placed on sterile maize-meal agar plates the following day. The fungus appeared on one plate six weeks later. (*b*) Soil from Lenton Experimental Station, Nottingham, collected on 10 December 1954 was used as inoculum in maize-meal agar, ten plates being prepared according to the Warcup (1950) method a week later. The fungus appeared on two of the plates after 4 weeks had elapsed.

Twomey (personal communication) has also found the same fungus from sawdust and poultry manure compost collected at Starcross, Devonshire, early in October 1954. Small portions of this compost were placed on sterile maize-meal agar plates on 26 January 1955 and the fungus was observed on 7 February 1955.

As we had more material from the second collection from Westley Heights than from the Nottingham one we are describing it as the type material of our new variety. The mycelium grew out from the inoculum over the surface of the agar. The hyphae were colourless, non-septate, and about 1·5 μ in diameter. Amoebae (mostly 40–60 μ in diameter) appeared to adhere to the vegetative hyphae; the fungus put out simple or branched, non-pedicellate haustoria into the animal and absorbed its cytoplasmic contents (Fig. 1 *a*). The fungus produced large numbers of erect conidiophores, each carrying a single terminal conidium. The conidiophores were colourless, non-septate and up to 150 μ high. The conidia were colourless, elongate-obovoid with rounded distal ends and strongly tapering bases; 12·5–37·5 μ (mostly 22–33 μ) long and 5·5–12 μ (mostly 7–11 μ) in greatest width (Fig. 1 *b*). These conidia germinated freely on the surface of the agar, germ tubes arising from either end of the spore (Fig. 1 *c*). After a period of asexual reproduction the fungus produced zygospores. The zygophoric hyphae arose from separate hyphae of the mycelium, intertwining around

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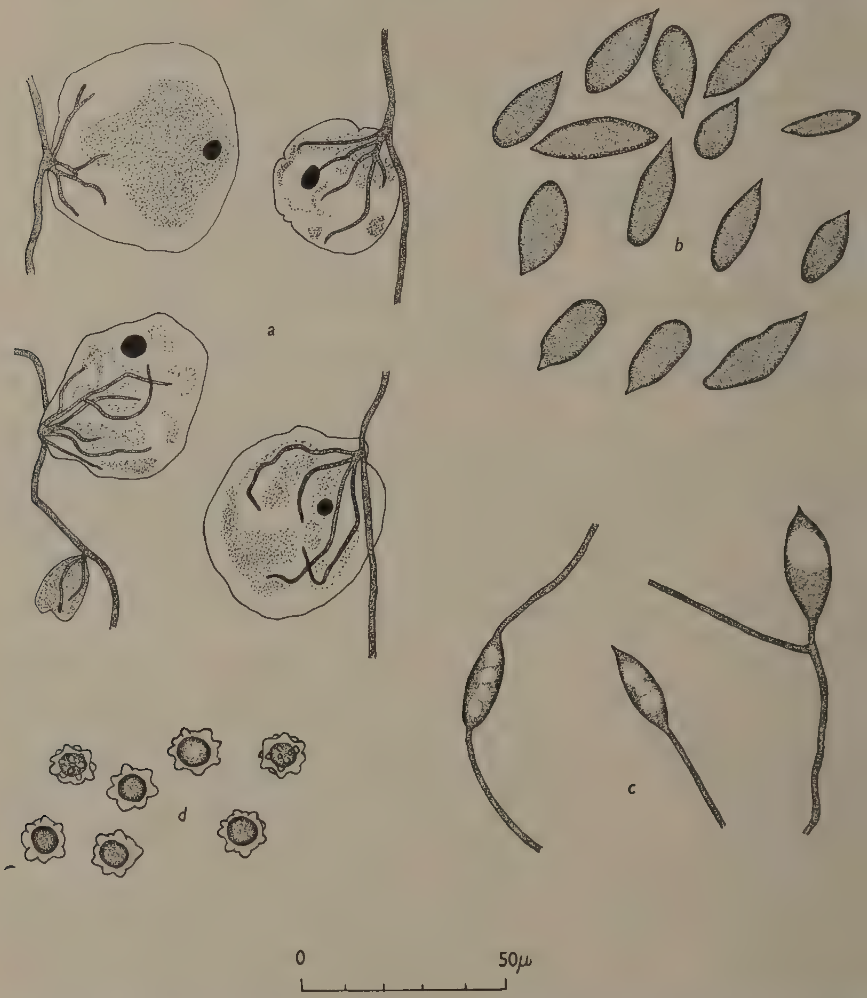

Fig. 1. *Stylopage araea* Drechsler var. *magna* var.nov. Type material from Westley Heights, Langdon Hills, Essex. *a*, hyphae with captured amoebae and haustoria; *b*, conidia; *c*, germinating conidia; *d*, zygospores.

each other before fusing to give rise to a zygosporangium. The zygospores were yellowish with a thick warty wall, 10–12 μ in diameter, with a central protoplast 6·5–8·5 μ in diameter (Fig. 1 *d*).

The fungus obtained from the soil from Nottingham agreed closely in structure of the mycelium and haustoria (Fig. 2 *a*) and in shape and position of the conidia, the spore size being 18–35 × 7–10 (Fig. 2 *b*). Fewer conidia were produced in this material than in that obtained from Westley Heights. The sexual apparatus was alike in material obtained from both sources (Fig. 2 *c*).

A number of species of *Stylopage* have been described which capture amoebae and produce ellipsoidal or elongate-obovoid conidia. *S. minutula* Drechsler (1945) has sparingly branched haustoria and much smaller conidia than our fungus. *S. cymosa* Duddington (1953) has bush-like haustoria, but usually has sympodial branching of the conidiophore, which bears up to eight conidia; in our material there was a single conidium at the tip of each conidiophore. Our fungus was very much like *S. araea* Drechsler (1935), the haustoria and the zygospores (Drechsler, 1939) particularly being alike both in method of formation and size (Drechsler's measurements were zygosporangium 9–12 μ in diameter, protoplast 6–8·5 μ in diameter). The conidiophores of our fungus were shorter than those described by Drechsler (his were 150–225 μ high) and the conidia were larger, his being 10–22 μ (mostly about 15 μ) long and 5·4–7 μ (mostly about 6·4 μ) wide. We have, therefore, described our fungus as a new variety of *S. araea*.

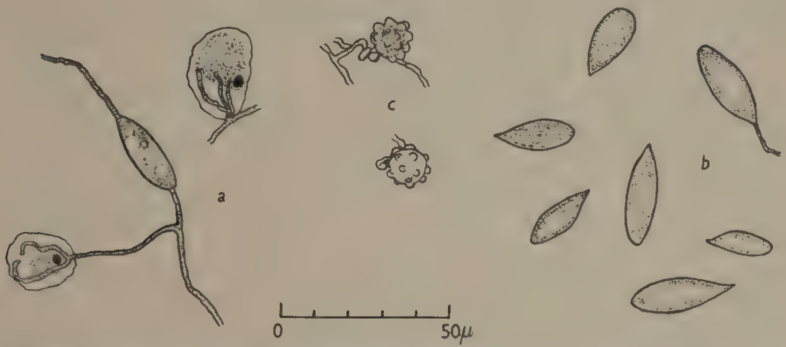

Fig. 2. *Stylopage areae* Drechsler var. *magna* var.nov. Material from soil from Nottingham. *a*, simple haustoria within small amoebae; *b*, conidia; *c*, conjugating hyphae and young zygospores.

Type material will be deposited in the herbarium of the Royal Botanic Gardens, Kew.

REFERENCES

DRECHSLER, C. (1935). Some non-catenulate conidial phycomycetes preying on terricolous amoebae. *Mycologia*, **27**, 176–205.

DRECHSLER, C. (1939). Five new zoopagaceae destructive to rhizopods and nematodes. *Mycologia*, **31**, 388–415.

DRECHSLER, C. (1945). Several additional phycomycetes subsisting on nematodes and amoebae. *Mycologia*, **37**, 1–31.

DUDDINGTON, C. L. (1953). A new species of *Stylopage* capturing amoebae in dung. *Ann. Bot., Lond.*, **17**, 127–129.

WARCUP, J. H. (1950). The soil-plate method for isolation of fungi from soil. *Nature, Lond.*, **166**, 117–118.

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OBSERVATIONS ON BLACK-POD DISEASE (*PHYTOPHTHORA PALMIVORA*) OF CACAO IN NIGERIA

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(With Plate 16 and 2 Text-figures)

The rotting of cacao pods caused by *Phytophthora palmivora* is referred to as black-pod disease. Typical disease symptoms were reproduced by artificial inoculation, using a pure culture of the fungus, but in general it was convenient to use sporangia from naturally infected pods as inoculum material.

In Nigeria, as contrasted with the Gold Coast, relatively few pods are infected at the base, in comparison with numbers infected laterally or distally. This circumstance is considered in relation to the anatomy of the pod and in connexion with the possibility of infection from the subtending cushion, via the pod stalk. Cushion infection is liable to occur when diseased pods are left on the trees, but such cushion infection is unimportant, because relatively few cushions (either 'healthy' or 'diseased') bear pods in the succeeding season.

Some sporangia take-off in 'dry' air, but more take-off under rain-splash conditions. Dispersion gradients were observed over both short (3 m.) and long (180 m.) distances. There was 'under-dispersion' at short distances from a source, but 'over-dispersion' due to extraneous sources occurred with long-distance dispersion. There is evidence that sporangia from the soil cause pod infection, and this phenomenon is offered as an explanation of 'over-dispersion'.

Black-pod incidence is mainly determined by numbers of pods available and climatic conditions. The temperature and humidity regimes in the months when the disease is prevalent were found to be in accordance with information on conditions favourable for germination of sporangia. However, an epidemic may not start, in spite of apparently favourable climatic conditions, if insufficient pods are present.

INTRODUCTION

The possibility of reducing cacao crop losses from pod disease in Nigeria was discussed by West (1936) in describing experiments started in 1931. These studies were the outcome of investigations by Dade (1927) in the Gold Coast. The writer has described recent measures for controlling black-pod disease (1953). The object of this paper is to present information on which current control methods are based.

MATERIALS AND METHODS

Most of the observations have been made on cacao trees at Department of Agriculture Experiment Stations; their positions have been described elsewhere, together with information on climates (Thorold, 1952*a*). The trees used were mostly of the Amelonado type which predominates in Nigeria. The soils of the cacao areas in general have been referred to by

Vine (1953*a*), who has discussed the soils of Moor Plantation in greater detail (Vine, 1953*b*).

Typical black-pod symptoms have resulted from inoculations of pods with *Phytophthora palmivora* grown on artificial medium. However, it was not convenient to use such cultures for routine and large-scale inoculation experiments, because sporangia are not generally produced abundantly. On the other hand, sporangia are produced abundantly on the surfaces of infected pods; in the earlier stages of such infections the fungus is relatively free from contamination by other organisms. In the course of numerous experiments, using inoculum consisting of sporangia from the surfaces of living pods, there has been no indication that any other organism has participated. When disease symptoms have resulted, they have invariably been those typical of black-pod disease.

Four different procedures (methods i to iv) have been used for pod inoculations.

Method (i)

A moist chamber consisting of a plasticine ring (about 1·25 cm. diam.) was formed on the surface of the pod. A suspension of sporangia in water was placed inside the ring which was then covered with glass. This procedure was inconvenient; therefore it was subsequently abandoned in favour of methods (ii), (iii) or (iv).

Method (ii)

A cellophane disk (about 3 mm. diameter), supported on a pin through its centre, was used to pick up sporangia for transference to a healthy pod, where the disk was placed and secured by pushing the pin a short distance into the pod. This method was useful when a relatively small quantity of sporangia was available for inoculation.

Method (iii)

Sporangia were picked up on the tip of a knife-blade and transferred to a healthy pod, generally with some wounding of the surface.

Method (iv)

A suspension of sporangia in water was sprayed on to healthy pods, using either an 'atomizer' spray or a 'flit-gun'.

It is customary to refer to mature or immature cacao fruits as *pods*; the word *fruit* will be used when reference to the state of maturity is necessary. The quantitative measure of black-pod incidence used now is the number of affected pods in relation to the total number of pods (healthy plus diseased). Annual totals are in relation to the conventional cocoa season, which runs from 1 April to 31 March.

Dade (1929) has described the nature of the compressed axillary branch system on which flowers and pods are borne; it is generally referred to as a *cushion*. The distance between pods was measured from cushion to cushion. In measuring distance from the ground, the point of attachment was also used.

The technique of marking the sporangia on a particular pod by application of a dyestuff ('Primuline') which fluoresces in ultraviolet light, has been described (Thorold, 1954). The procedure is a refinement of the method adopted previously for trapping sporangia (Thorold, 1952 *b*).

THE CAUSAL FUNGUS

Isolations of *P. palmivora* from diseased cacao pods in Nigeria, have been found to be 'typical' in culture, as defined by Ashby (1929) with respect to general characters including early production of sporangia. There have been no indications of important local variations with respect to the characters of the fungus, nor as regards the nature of the pod rot it causes. Variations in dimensions of sporangia were in respect to age and nature of substratum, as shown in Table 1. The ranges in length and in diameter shown in Table 1 are within the ranges given by Rorer (1910) for the black-pod fungus (30–60 × 21–30 μ).

Table 1. *Mean values (μ) of length, diameter and length/diameter ratio of* Phytophthora palmivora *sporangia observed in Nigeria*

Substratum	No. sporangia measured	Length	Diameter	Ratio
Pod (advanced infection)	51	37·5	27·0	1·4
Pod (recent infection)	63	35·3	26·6	1·3
Maize-meal agar culture	25	33·4	22·0	1·5
Stem (artificial infection)	25	32·8	23·4	1·4

P. palmivora has not yet been observed locally on other hosts within the region of cacao cultivation. Ashby (1929) found that oogonia were produced by strains of the 'cacao' group of the fungus only when mixed with strains of another group of the same fungus. The apparent absence of alternative hosts simplifies control measures and may limit the possible variability of the pathogen in Nigeria.

CONDITIONS ASSOCIATED WITH GERMINATION OF SPORANGIA

Rorer (1910) studied the life history of *P. palmivora* and showed that infection resulted either directly, by the entrance of germ tubes from zoospores or sporangia, or indirectly through the further production of sporangia on the surface. The occurrence of secondary sporangia has been observed occasionally in Nigeria. Sporangia germinate readily in water, zoospores being produced in about 30 min., as was found by Rorer (1910). In the absence of water but under conditions of adequate humidity, germ tubes are generally produced instead of zoospores or secondary sporangia. Attempts have been made to determine the minimum moisture conditions necessary for germination, but on account of the practical difficulties inherent in measuring and maintaining specified humidities within a range near to saturation, precise information was not obtained. It seemed that germination did not occur when relative humidity (R.H.) was persistently less than about 95 %. Some sporangia germinated when the R.H. fluctuated between 98 % (maximum) and 92 % (minimum). When sporangia were subjected to relatively low humidities (30–80 %) for a period of 11 hr., there was a period of delay before germination occurred under favourable conditions (98–100 % R.H.). Sporangia retained at 80 % R.H. germinated after a period of about 12 hr., but sporangia retained at 30 % R.H. germinated after a period of 24 hr. under favourable conditions.

LENGTH OF PERIOD BETWEEN INOCULATION AND APPEARANCE OF SYMPTOMS

When inoculation was accompanied by wounding (method iii), disease symptoms generally developed within 3 days. In the absence of wounding (method iv), the interval between inoculation and the appearance of black-pod symptoms varied considerably, as shown in Table 2.

Table 2. *Numbers of pods classified according to length of time from inoculation by spraying with sporangia to appearance of disease symptoms*

Class (no. days)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Frequency (no. pods) ...	0	2	7	29	25	15	9	7	3	10	4	5	2	2	2	0	122

The number of black-pod spots which developed on healthy pods, following inoculation by spraying with sporangia, varied from 1 to 8. This latter number was exceptional, because the mean number of spots per pod was 1·4 in one typical series of observations. It is evident that many sporangia do not cause infection, or fail to produce visible symptoms. The inconsistency of results from inoculation experiments without wounding (method iv), has impeded both tests for possible resistance and small-scale tests of different fungicide treatments. The relatively greater success of inoculation accompanied by wounding (method iii), is presumably the consequence of removing some of the obstacles to fungus penetration and development.

SITE OF POD INFECTION

In the course of studies on black-pod disease in the Gold Coast, Dade (1927) classified infected pods, according to the site of infection, as lateral, distal and proximal. When 258 pods from three localities in Nigeria were similarly classified, the results differed from those in the Gold Coast. Dade (1928) drew attention to the relatively high incidence of proximal infections (65·2 %), in connexion with stem cankers resulting from infection of flower cushions by *P. palmivora*. It will be seen from Table 3 that proximal infections were less common in Nigeria (14·3 %).

Table 3. *Numbers of black-pods expressed as percentages and classified according to site of infection, from observations in the Gold Coast (Dade, 1927) and in Nigeria*

Infection site	Lateral	Distal	Proximal	Total
Gold Coast	24·0	10·8	65·2	100·0
Nigeria	38·0	47·7	14·3	100·0

RELATIONSHIP BETWEEN LENGTH OF POD AND SITE OF INFECTION

Cacao fruits can become infected at all stages from setting to maturity. Observations in Nigeria suggest that the relative frequencies of different infection sites may be affected by fruit length. It was found that the mean length of distally infected fruits tended to be less than the mean length of either laterally or proximally infected fruits, as shown by one typical series of observations summarized in Table 4. These observations can be interpreted as indicating that distal infections tend to occur on relatively shorter and younger fruits, as compared with laterally and proximally infected fruits. The average lengths of fruits at different ages, from setting to maturity in Nigeria, are in general conformity with detailed measurements recorded by Waters & Hunter (1929) in the Gold Coast.

Table 4. *Numbers and mean length (cm.) of fruits classified according to infection site*

Infection site	No. fruits	Fruits (percentage of total)	Mean length	S.E. mean	Difference between means
Lateral	885	42·7	14·4	±0·075	—
Proximal	571	27·5	13·2	±0·113	1·2*
Distal	617	29·8	11·3	±0·115	1·9*
Total	2073	100·0	—	—	3·1*

* Difference significant at 1 % level.

Dade (1927) suggested that proximal infection might be favoured through moisture being retained in the annular depression where the stalk is inserted. The writer has observed that moisture is commonly retained at the distal ends of young fruits. Under conditions in Nigeria, the annular depression at the base may not necessarily be favourable for infection as compared with the distal end of the pod. Anatomical features near the two extremities (Plate 16, figs. 1, 2) suggest that the proximal region may offer greater difficulties for penetration by germ tubes as compared with the tip and sides of the pod. Orellana (1953) has described the three layers constituting the pod wall, as exocarp (cuticle and a single layer of epidermal cells), mesocarp and endocarp, respectively. The mesocarp consists of several layers of parenchyma cells with occluded mucilage cavities. The endocarp consists of sclereids and fibres, forming a relatively hard layer (1·0–1·5 mm. thick). It appears from Pl. 16, fig. 2, that at the base of the fruit the endocarp layer is particularly well developed and the mesocarp is relatively thin, as compared with lateral and distal regions (Pl. 16, fig. 1). It is suggested that this dissimilarity in superficial tissues at the base of the fruit as compared with its tip, may prejudice proximal infection and favour distal and lateral infection, as observed in Nigeria (Table 3). There is a cavity at the tip, surrounding the persistent style (Pl. 16, fig. 1); although this depression is small (about 1 mm. diameter), it is relatively large compared with the size of a sporangium (about 0·04 mm.). Therefore, it may be a suitable place for sporangia to germinate and cause infection.

PROGRESS OF INFECTION

(*a*) *External development*

Observations on a number of inoculated pods suggest that the area of discoloration (brown, darkening later) is approximately doubled on each succeeding day, as shown in Table 5; similar results were obtained when development was measured in naturally infected pods. When the development of spots was compared on pods of different ages, it was found that the rate of increase tended to be slower when the pod was nearly mature. When pods were removed from the tree after inoculation, subsequent development of the discoloured area was similar to that in intact pods.

Table 5. *Mean areas (cm.²) of black-pod spots on successive days*

No. days from first appearance of spot	0	1	2	3	4
Mean area (cm.²)	10·5	25·1	51·1	102·7	192·1

(*b*) *Internal development*

An attempt was made to follow the course of infection internally. For this purpose, twenty pods of similar age on one tree were inoculated (method iii). Subsequently, a pod was removed every day for examination internally. When the infection spot first appeared (day 0), infection had extended inwards about 1 cm., after that, the following sequence of events was noted: day 6, central core infected; day 9, distal end of stalk infected; day 12, proximal end of stalk infected; day 14, infection of cushion indicated by discoloration; day 17, pod contents completely rotted. From these limited observations, it seems that cushion infection is liable to occur if an infected pod remains on the tree for a period of about 2 weeks from first appearance of the spot.

EFFECT OF *PHYTOPHTHORA PALMIVORA* ON OTHER PARTS OF THE PLANT

(*a*) *Cushion infection*

In order to study the possible effects of cushion infection, records were kept of all fruits which developed on 551 labelled cushions from which old black-pods had been removed. The results from these observations are summarized in Table 6. If the year of labelling is rated as 100, in three succeeding years the numbers of fruiting cushions were approximately 4, 20 and 17. Only a small percentage (less than 1 %) of the 'diseased'

Table 6. *Numbers of 'diseased' cushions setting fruit per 100 cushions observed, and numbers of fruits with proximal infection per 100 cushions*

Year of observation	1951	1952	1953
Percentage of cushions setting fruit	4·4	19·6	16·5
Percentage of cushions having fruits with proximal infection	0·9	0·4	0·3

cushions gave rise to subsequent pod infection, whilst there was an indication that the incidence of cushion infection declined in the course of 3 years (0·9–0·3 %). It seemed possible that the small number of cushions setting fruit in the year following the removal of black pods might be a result of cushion infection. Accordingly, both 'healthy' and 'diseased' cushions were labelled in January 1952. The results obtained during 1952 are summarized in Table 7. The indication that fruit setting was relatively enhanced on 'diseased' cushions may have been fortuitous, because in another similar series of observations the percentages were 5·3 % in the case of 'healthy' cushions and 3·7 % in the case of 'diseased' cushions. Amongst the factors which determine fruit setting on a cushion in the year following the presence of one or more pods, the possible effect of cushion infection is apparently not important.

Table 7. *Percentage of cushions setting fruit and percentage of cushions having fruits with proximal infection, on 'healthy' and 'diseased' cushions respectively*

	Healthy cushions	Diseased cushions
Percentage of cushions setting fruit	2·8	8·6
Percentage of cushions having fruits with proximal infection	0·0	0·4

It seems that fungicide control of black-pod disease in Nigeria has been relatively successful (Thorold, 1953) because infection generally takes place through the exterior of the pod rather than internally through the stalk.

(*b*) *Stem and leaf infection*

Young chupons (vertical stems) have been successfully infected by spraying them with a suspension of sporangia (method iv). Brown lesions developed on these stems 5 days after inoculation; sporangia were sparsely produced later. There was a wilting of young leaves associated with the lesions below, but there were no discrete leaf infections. The effect on chupons, following artificial inoculation, was in general accordance with the chupon-wilt symptoms described by Rorer (1910). Casual observations suggest that the natural occurrence of chupon-wilt, due to *P. palmivora* infection, is uncommon in Nigeria. No evidence of natural infection of leaves, nor of radial branches, has been observed in Nigeria.

START OF SPORANGIA PRODUCTION

Production of sporangia generally begins on the pod between 8 p.m. and 6 a.m., during the night following the second day of visible symptoms. Using inoculation method ii, it has been shown that the earliest formed sporangia can infect a healthy pod. The general sequences of symptoms and time of sporangia production have been illustrated diagrammatically (Thorold, 1953), and need not now be considered further.

Cessation of sporangia production

Production of sporangia becomes general over the surface of a pod within a period of from 5 to 10 days from the first appearance of symptoms. The pod may become thoroughly permeated by the fungus (*P. palmivora*) within a period of 1–2 weeks, then secondary fungi and bacteria generally invade the rotted pod. One diseased pod was apparently associated with infection of nearby healthy pods over a period of 20 days.

Take-off of sporangia

Ashby stated (1929) that the sporangia of *P. palmivora* fall from their sporangiophores when mature. This statement has been confirmed in experiments when an infected pod with abundant sporangia was placed in a closed container and supported over a microscope slide, so that there was a distance of about 1 cm. between the surface of the pod and the surface of the slide. The mean numbers of sporangia which landed on the slides in 24 hr. periods, in the course of three experiments, were 0·4, 1·0 and 3·4 sporangia per cm.^{2}, respectively. These experiments showed that sporangia were deposited in still air from an infected pod, without the agency of free moisture. There was no reason to suppose that the artificial condition imposed by using detached pods invalidated these experiments. The numbers of sporangia on slides were of a similar order to those of sporangia trapped near attached pods (an average of 2 to 5 sporangia per cm.^{2}, in a 12 hr. period).

The writer has reported observations which showed that sporangia of *P. palmivora* take-off from infected pods in 'dry' air (Thorold, 1952 *b*, 1954), by using 'vaselined' disks of cellophane (3 mm. diam.) mounted on pins above the sporangia-bearing surfaces of pods. The number of sporangia which take-off in splash-droplets generally exceeds the number which take-off in 'dry' air. In certain instances, after periods of considerable rainfall, the numbers or sporangia were of the order of 50 to 100 per disk, and could not conveniently be counted, because there were many clumps of sporangia. On account of the wide range in numbers of sporangia observed on the disks, a transformation to logarithms was used for statistical analysis, as discussed by Williams (1952), in connexion with insect-trapping experiments. Geometric means have been transformed back to the original units for the present discussion of results.

Gregory & Stedman (1953) have drawn attention to the various factors affecting the deposition of spores on plane surfaces. The angle of presentation of the trap may be expected to be particularly important in this connexion. Such positional effects have not been detected with respect to *P. palmivora*, possibly on account of practical difficulties involved in mounting the disks uniformly with respect to the irregular curved surface of the pod.

Gregory (1952) and Hirst (1953), have described large diurnal variations in numbers of fungus spores trapped from the air 'spora'. When two sets each of ten disks were exposed for 12 day-time hr. and for 12 night-time hr., the mean numbers of *P. palmivora* sporangia were 5·33 for day-time and 5·87 for night-time, respectively. The difference between these means (0·54) was not significant. Therefore, under the conditions of this experiment, there was no important differential effect of day-time conditions as compared with night-time conditions, with respect to take-off of sporangia.

Table 8. *Average number of sporangia per disk in a 12 hr. period*

Distance from pod (cm.)	0·5	1·0	2·0	3·0
Mean no. sporangia	1·62	2·72	3·21	3·48

In the trapping experiments described so far, the disks were all set at approximately the same distance from the pod surface, in any one series of experiments. The distances employed varied between 0·5 and 1·0 cm. Experiments have been undertaken to compare the numbers of sporangia caught on disks set at four different distances, which ranged from 0·5 to 3·0 cm., from the pod surface. The results from one such experiment are summarized in Table 8. The table shows that there was a tendency for the number of sporangia caught to increase with increasing distance from the pod, up to 3·0 cm. It is to be noted that the source of sporangia was large (about 200 cm.^{2}) in relation to the area of each disk (0·07 cm.^{2}). A flat gradient would be expected at relatively short distances from an area source (Gregory, 1945). A few attempts to trap sporangia on disks at about 6 cm. from the pod surface were not successful.

DISPERSION OF SPORANGIA

(*a*) *Short-distance dispersion*

Infected pods are evidently an important source of the sporangia which may cause infection of healthy pods in the course of the season. However, two other possible sources, namely old black-pods and the soil, need to be considered. Relevant observations are summarized in Table 9.

Table 9. *Numbers of total* (*healthy plus diseased*) *pods* (T.P.), *and numbers of black-pods* (B.P.) *expressed as percentages of total pods and grouped according to distance from the source, when the source was either a single inoculated pod, or a heap of old black-pods, or the soil in the vicinity*

(For each source, the value of the slope of the line relating the number of black-pods and the logarithm of the percentage of uninfected pods has been calculated (*b*), also the value of the ratio of the slope of the expected line to the slope of the observed line (*K*), as considered by Gregory (1948).)

Distance from source ...	0–39 in. (0–1 m.)		40–79 in. (1–2 m.)		80 in. and over (over 2 m.)			
	T.P.	B.P.	T.P.	B.P.	T.P.	B.P.	*b*	*K*
Inoculated pod	89	56·2	67	11·9	80	3·8	−0·00662	0·66
Soil	57	56·2	154	33·1	176	7·4	−0·00663	0·66
Heap of black-pods	46	45·7	65	21·5	165	6·7	−0·00608	0·71

Table 9 shows that the dispersion gradient was similar in the case of each of the three sources observed. The tabulated values of *b* and *K* indicate 'under-dispersion' (Gregory, 1948) with respect to each of the three sources. It is to be noted that the numbers of total pods at the different distances from the source (Table 9) varied greatly (46–176). It is probable that the number of possible infections was limited by both number and distribution of healthy pods.

Particular interest attaches to the occurrence of 'under-dispersion' because preliminary observations had shown that stray sporangia might confuse the results. The complication arising from extraneous sources has already been considered in discussing results from observations on dispersion up to a distance of 100 m., from a black-pod source (Thorold, 1952 *b*). An attempt was made to assess the amount of extraneous infection at the start of the experiment on dispersion from inoculated pods. The sporangia-bearing surfaces of the source pods were sprayed with a saturated solution of 'Primuline' (Thorold, 1954). Subsequently, the healthy pods which became infected were examined for the presence of ultraviolet fluorescence, which would suggest infection from a source-pod which had been treated with 'Primuline'. The majority (74 %) of the infected pods were found to have fluorescence associated with the infected areas. In the case of the remainder (26 %), fluorescence was not detected, suggesting that infection might have resulted from extraneous infection.

It was not practicable to employ this 'Primuline' technique when making observations on dispersion from soil nor from the heap of black-pods. However, certain subsidiary observations were made which support the evidence from the main experiment.

Old black-pods

When fourteen healthy pods were placed on a heap of black-pods about 1 year old, all developed infection. On the other hand, when six healthy pods were placed in contact with a heap of black-pods about 2 years old, three developed black-pod, whilst three remained healthy. From these observations, it was concluded that *P. palmivora* was still present in the 2-year-old pods, but that they constituted a relatively impotent source of infection compared with the 1-year-old pods. Orellana (1954) has reported infection of healthy pods when placed within a 'cacao shell dump pile'—observations in accordance with those made in Nigeria. Wright (1930) has shown in the Gold Coast that *P. palmivora* can persist in soil and in old cacao shells for periods of 4 months, but his observations appeared to show that this fungus was incapable of competing with soil saprophytes for longer periods.

Soil

Instances have occurred when severe black-pod infection has developed on particular trees in the absence of a nearby pod source. In the case of one such tree, soil infection was detected by placing seven healthy pods on the ground near the tree, where all developed infection. Other healthy pods placed on the ground in the vicinity did not develop infection. Pods are sometimes produced from cushions near the base of the tree; it is not uncommon for such basal pods to become infected on their lower surfaces, which are in close contact with the soil. It has been possible to repeat the incidence of such infection by putting a severed healthy pod in the place of the originally infected pod. Infection of healthy pods by the use of soil as 'inoculum' has been reported by Orellana (1954). It is not known whether *P. palmivora* persists in the soil as mycelium, or in the form of 'spores' (sporangia, chlamydospores or oospores). In this connexion, it is interesting to note that Legge (1952) has recovered ungerminated cospores of *Phytophthora* spp., after a year in the soil. The existence in the soil of a fungistatic factor has been considered more fully by Dobbs & Hinson (1953). It is possible that the germination of *P. palmivora* sporangia is inhibited in the soil, but germination may occur when these sporangia are in contact with moisture on the pod surface. It is probable that take-off of sporangia in the soil occurs in splash droplets, when vertical air movements may carry the sporangia to greater distances. If this hypothesis can be verified, it will serve to explain the survival of sporangia in the soil through the dry season, in such a condition that they can initiate and help to maintain epidemics during the wet season.

(*b*) *Long-distance dispersion*

Thorold (1952 *b*) described observations on black-pod dispersion from a source, up to a distance of about 100 yards (90 m.). Subsequent observations on dispersion up to a distance of about 200 yards (180 m.) have been considered summarily (Thorold, 1953). An area of 10 acres at Agodi, near Ibadan, comprising over 4000 trees, has been used for two seasons (1952–4) for observations on black-pod dispersal. In both seasons all trees were inspected every other day, in order to record and remove black-pods in the earliest symptom stage (before the start of sporangia production). In 1952, the black-pods were heaped at the base of a central tree which served as the source of infection. In the second season, the heap of old pods was allowed to remain but all new black-pods were removed from the area. The numbers of black-pods and of healthy pods were grouped according to distance from the source. The results obtained in the course of two seasons are summarized in Table 10. It is seen from Table 10 that in 1952 there was a decreasing gradient of infection from the source, with respect to both percentage of diseased trees and numbers of diseased pods. However, there are irregularities, notably over the range 41–80 m., from the source. In 1953, there was little evidence of an infection gradient, except that at 0–10 m. the percentage of diseased trees (52·7), and the number of diseased pods per 100 trees (136·5), were both greater than at other distances from the source. It is to be noted that the values in these columns are all smaller than the corresponding values at similar distances from the source in 1952. It is reasonable to assume that this difference between the results in the two seasons is due to there having been a potent source (recent black-pods) in 1952 and a less potent source (old black-pods) in 1953. In both seasons, the observed numbers of diseased pods exceeded the expected numbers of diseased pods (Gregory, 1948). Therefore, there was 'over-dispersion' in both seasons, the ratio of the slope of the expected line to the slope of the observed line being found to be 2·08 in 1952 and 2·37 in 1953; these values are significantly greater than unity. The occurrence of 'over-dispersion' to such a marked degree can be partly explained by the fact that at certain distances from the source there were nearby trees in private ownership, where black-pod disease occurred. It is probable that these untreated trees acted as subsidiary sources of black-pod infection. However, the likelihood of such extraneous infection does not adequately explain the phenomenon of 'over-dispersion' at all distances from the source. It is suggested that there may have been infection from the soil throughout the experiment area. Short-distance dispersion of sporangia from the soil has been considered above (p. 443).

Table 10. *Incidence of black-pod disease over a range of distances from a central source at Agodi in two seasons*

	1952–3			1953–4		
Distance from source (m.)	Diseased trees (percentage of total trees)	No. diseased pods (per 100 trees) observed	No. diseased pods (per 100 trees) expected	Diseased trees (percentage of total trees)	No. diseased pods (per 100 trees) observed	No. diseased pods (per 100 trees) expected
0–10	77·2	224·6	147·8	52·7	136·5	74·9
11–20	59·3	164·1	89·8	42·4	107·0	55·2
21–30	61·5	176·7	95·3	39·0	117·5	49·4
31–40	55·4	188·2	80·8	39·8	120·1	50·8
41–50	64·2	192·0	102·7	37·9	88·1	47·6
51–60	62·7	203·8	98·6	41·8	123·8	54·1
61–70	66·5	212·6	109·4	41·3	107·0	53·3
71–80	62·3	224·9	97·6	38·5	90·8	48·6
81–90	53·6	129·2	76·7	31·3	52·2	37·5
91–100	52·7	127·0	74·8	27·8	59·6	32·6
101–110	54·7	141·6	79·2	40·9	100·6	52·6
111–120	51·9	133·4	73·2	29·5	81·9	35·0
121–130	47·1	104·8	63·6	38·8	88·5	49·1
131–140	58·6	123·3	88·2	38·9	105·3	49·3
141–150	38·1	73·2	47·9	20·2	45·8	22·6
151–160	15·3	23·7	16·6	6·9	8·6	7·2
161–170	17·0	25·5	18·7	19·5	19·5	21·7
171–180	17·4	30·4	19·1	8·7	13·0	9·1

EFFECT OF CLIMATE ON THE INCIDENCE OF BLACK-POD DISEASE

Dade (1930) recorded humidity changes in connexion with pod infection by *P. palmivora*. He concluded (p. 127) that the important factors were the length of time during which the pods are invested with a film of moisture, and the proportion of actively infectious pods. Attempts to define the lower limits of humidity for germination of sporangia have been referred to above (p. 437). Evidence was found that a humidity of about 80% R.H. may be critical. The incidence of black-pod in Nigeria varies from month to month, but tends to follow a similar course from year to year. Typical monthly trends for two localities (Agodi and Owena) are shown in Table 11. This table indicates that black-pods did not occur at Agodi nor at Owena until June. However, four black-pods were recorded at Owena in May 1952, but this number was too small to be represented in the table (less than 0·05 % of total). Owena is in an area of relatively high rainfall compared with Agodi, as shown in Table 12.

Wet-bulb and dry-bulb temperatures were recorded at 9 a.m. and at 2 p.m. (about 5 ft. from the ground) in the cacao plantation at Agodi. The corresponding R.H. values were determined and monthly averages obtained. The results, plotted as continuous lines in Text-fig. 1, demonstrate average diurnal temperature and humidity ranges in all months (1–12); there are also two families of curves (broken lines) corresponding with the procedure adopted by Evans (1930). One family of lines shows constant saturation deficit from 1·0 to 40 mb. (0·75–30 mm. Hg), the other family of lines shows constant absolute humidity from 10 to 40 g./m.^{3} (10–42 mm. Hg). The continuous lines, which indicate diurnal temperature and humidity conditions during each month, may be considered as falling into two groups, namely those months in which mean relative humidity fell below 80 % (December (12), January (1), February (2), March (3) and April (4)), these are the months in which little or no black-pod occurs (Table 11). The other group comprises the period May (5) to November (11), in which mean R.H. did not fall below 80 %, these are the months in which black-pod may occur to a greater or less degree. However, two observations in a 24 hr. period cannot adequately represent the diurnal march of temperature and humidity conditions. These regimes are illustrated in Text-fig. 2, which shows observations made at 2 hr. intervals for 24 hr. periods (at a height of 5 ft.) in a cacao field at Moor Plantation.

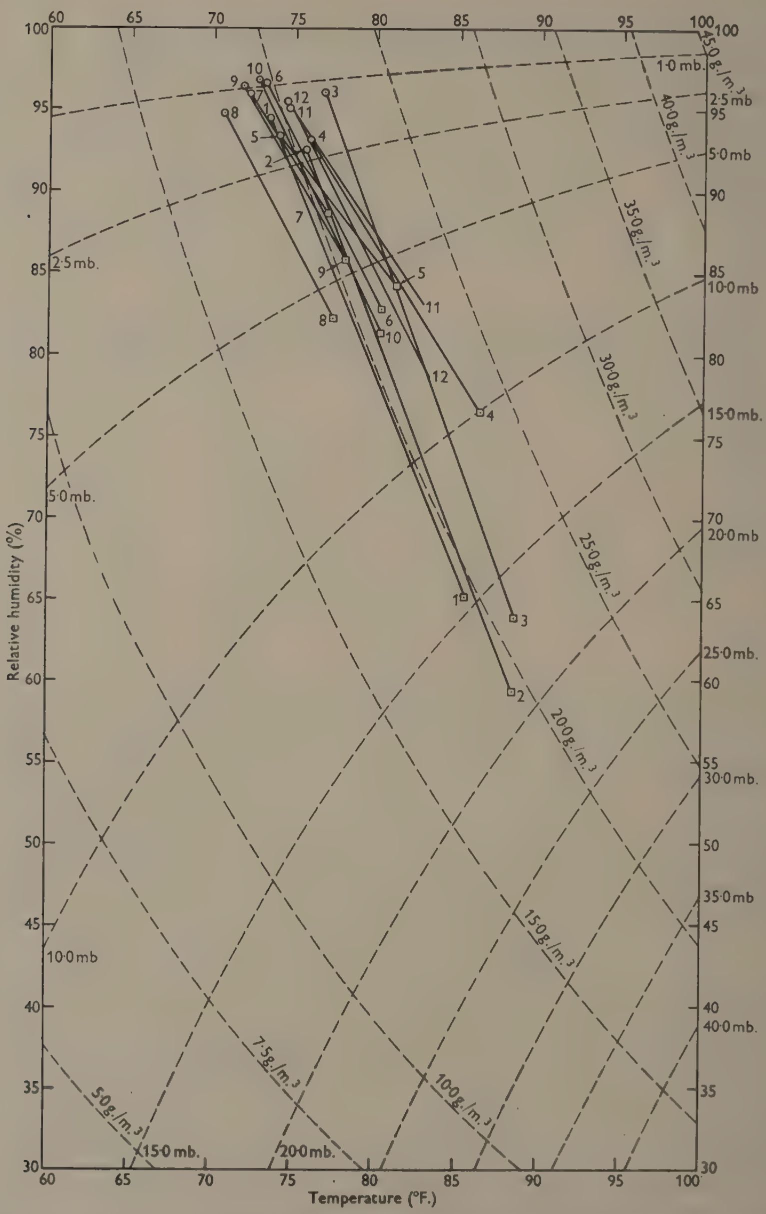
Table 11. *Numbers of black-pods recorded each month at Agodi and at Owena, expressed as percentages of the total numbers of black-pods for the whole season (April 1952 to March 1953)*

	A.	M.	J.	Jl.	A.	S.	O.	N.	D.	J.	F.	M.	Total
Agodi	0·0	0·0	0·1	5·6	9·4	20·8	36·9	21·2	5·7	0·3	0·0	0·0	100·0
Owena	0·0	0·0	0·4	3·8	15·8	36·2	27·6	11·9	4·3	0·0	0·0	0·0	100·0

Table 12. *Monthly rainfall (inches) at Owena and at Agodi in 1952/3*

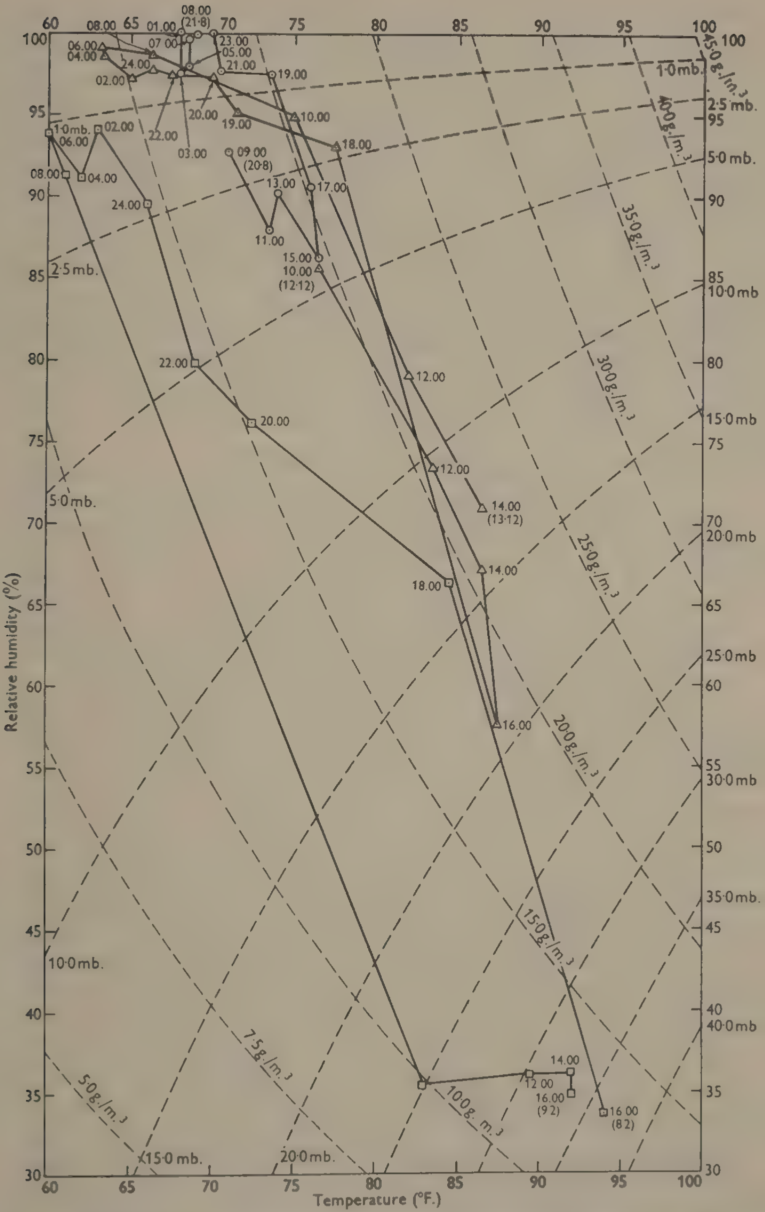
	A.	M.	J.	Jl.	A.	S.	O.	N.	D.	J.	F.	M.	Total
Agodi	4·8	4·2	4·7	7·3	1·8	5·3	4·7	3·8	0·1	0·0	3·3	2·6	42·6
Owena	4·6	6·7	11·0	8·0	9·4	13·8	9·5	1·2	0·0	0·0	1·0	3·0	68·2

The February data represent typical dry-season conditions (R.H. not reaching 95 % and R.H. below 80 % for over 12 hr.), as contrasted with August, representing typical wet-season conditions (R.H. above 95 % for more than 12 hr. and R.H. not falling below 85 %). December is nominally a dry-season month, but it seems to be intermediate (R.H. above 95 % for more than 12 hr. and R.H. below 80 % for only 6 hr.). Therefore, suitable conditions for infection can occur in December, when there may be an appreciable black-pod incidence (Table 11), in virtual absence of rainfall (Table 12).



Text-fig. 1. Mean monthly temperature and mean monthly relative humidity values at 9 a.m. (⊙) and at 2 p.m. (⊡), joined by straight lines, for each of 12 months (1–12), from wet-bulb and dry-bulb temperature observations in a cacao field at Agodi. Curves (broken lines) of constant saturation deficit in millibars (mb.) and constant absolute humidity in grams water per cubic metre of air (g./m.³).

–△–, 12–13 December 1949; –⊡–, 8–9 February 1950; –⊙– 20–21 August 1950.



Text-fig. 2. Temperature and relative humidity values from wet-bulb and dry-bulb temperature observations at 2 hr. intervals in a cacao field at Moor Plantation, during December and February (dry season) and during August (wet season). Curves (broken lines) of constant saturation deficit in millibars (mb.) and constant absolute humidity in grams water per cubic metre of air (g./m.^{3}).

-△-, 12–13 December 1949; -⊡-, 8–9 February 1950; -⊙-, 20–21 August 1950.

Combined effects on black-pod of climate and number of pods

Although black-pods did not occur in 1952 in appreciable numbers until June (Table 11), it will be noted from Table 12 that there was appreciable rainfall (over 4 in.) in both April and May 1952. It is shown in Table 13 that no pods were harvested in April, but harvesting began earlier at Owena (May) as compared with Agodi (July). It seems from observations summarized in Tables 11–13 that the black-pod epidemic did not start until there was a sufficient number of pods present, in addition to adequate rainfall. Thomas (1932) drew attention to information given by Auchinleck & Knowles (1926), which showed that on stations in the Gold Coast having a well-marked dry season, the main crop of cacao is later than in those districts which are subject to less variation in rainfall. The Cameroons provide an example of an area where the dry season is less well marked compared with either Agodi or Owena.

Table 13. *Numbers of pods harvested each month at Owena and at Agodi, expressed as percentages of the total pods harvested*

	A.	M.	J.	Jl.	A.	S.	O.	N.	D.	J.	F.	M.	Total
Agodi	0·0	0·0	0·0	3·8	6·9	28·4	21·3	13·6	22·1	3·0	0·9	0·0	100·0
Owena	0·0	0·4	1·1	1·2	0·7	12·8	32·9	37·8	9·1	2·1	1·9	0·0	100·0

Table 14. *Monthly percentages of crop harvested and rainfall at Molyko Plantation (data from West & Voelcker, 1942)*

	A.	M.	J.	Jl.	A.	S.	O.	N.	D.	J.	F.	M.	Total
% total crop	0·4	1·4	7·8	29·7	34·7	16·1	2·1	1·9	2·0	2·6	0·9	0·4	100·0
Rainfall (in.)	7·4	6·9	12·5	16·1	22·9	17·6	10·7	6·7	1·5	0·8	1·6	6·0	110·7

West & Voelcker (1942) gave data on black-pod incidence, cacao harvesting and rainfall, in the Cameroons. Part of the information in their table II is used for Table 14, with respect to Molyko Plantation, where 5·7 % of the crop was apparently lost through black-pod disease in May, later the percentage loss was as great as 82·2 % in September. Table 14 shows that under conditions of a relatively well-distributed rainfall (no month without precipitation, cf. Table 12), some cacao crop was harvested in all months (cf. Table 13). There was an appreciable loss from black-pod at Molyko in May (5·7 %) as compared with a negligible proportion lost in that month at Owena and none at Agodi.

The conclusion is reached, that when humidity conditions (Text-figs. 1, 2) are considered in relation to monthly occurrences of pods (Tables 13, 14) a satisfactory explanation is given for the trend in black-pod incidence throughout the year in Nigeria (Table 11). This conclusion also provides the basis for timing spraying programmes for black-pod control.

REFERENCES

Ashby, S. F. (1929). Strains and taxonomy of *Phytophthora palmivora* Butler (*P. faberi* Maubl.). *Trans. Brit. mycol. Soc.* **14**, 18–38.

Auchinleck, G. C. & Knowles, C. H. (1926). Yields of cacao in experiment stations. *Bull. Dep. Agric. Gold Cst*, **4**, 3–44.

Dade, H. A. (1927). Economic significance of cocoa pod disease and factors determining their incidence and control. *Bull. Dep. Agric. Gold Cst*, **6**, 1–58.

Dade, H. A. (1928). The relation between diseased cushions and the seasonal outbreak of 'black-pod' disease of cacao. *Bull. Dep. Agric. Gold Cst* (*Year Book*), **13**, 85–88.

Dade, H. A. (1929). Origin and spiral arrangement of cushions in cacao. *Bull. Dep. Agric. Gold Cst* (*Year-Book*, 1928), **16**, 147–150.

Dade, H. A. (1930). The determination of incidence of black-pod disease of cacao. *Bull. Dep. Agric. Gold Cst* (*Year-Book*, 1930), **23**, 122–128.

Dobbs, C. G. & Hinson, W. H. (1953). A widespread fungistasis in soils. *Nature, Lond.*, **172**, 197–199.

Evans, G. C. (1930). Ecological studies on the rain forest of Southern Nigeria. II. The atmospheric environmental conditions. *J. Ecol.* **27**, 436–482.

Gregory, P. H. (1945). The dispersion of air-borne spores. *Trans. Brit. mycol. Soc.* **28**, 26–72.

Gregory, P. H. (1948). The multiple-infection transformation. *Ann. appl. Biol.* **35**, 412–417.

Gregory, P. H. (1952). Spore content of the atmosphere near the ground. *Nature, Lond.*, **170**, 475–477.

Gregory, P. H. & Stedman, O. J. (1953). Deposition of air-borne *Lycopodium* spores on plane surfaces. *Ann. appl. Biol.* **40**, 651–674.

Hirst, J. M. (1953). Changes in atmospheric spore content: diurnal periodicity and the effects of weather. *Trans. Brit. mycol. Soc.* **36**, 375–393.

Legge, Betty J. (1952). Use of glass fibre materials in soil mycology. *Nature, Lond.*, **169**, 759–760.

Orellana, R. C. (1953). Infection and tissue changes of *Theobroma cacao* L., by *Phytophthora palmivora*. Butler. *Turrialba*, **3**, 167–172.

Orellana, R. C. (1954). Contribution to the study of survival, dissemination and control of *Phytophthora* on cacao. *Cacao*, **3**, 10. (Inter-American Cacao Center, Turrialba, Costa Rica.)

Rorer, J. B. (1910). Pod-Rot, Canker and Chupon-Wilt of Cacao caused by *Phytophthora* sp. *Bull. Dep. Agric., Trin. Tob.* **9**, 79–120.

Thomas, A. S. (1932). The dry season in the Gold Coast and its relation to the cultivation of Cacao. *J. Ecol.* **20**, 263–269.

Thorold, C. A. (1952*a*). The epiphytes of *Theobroma cacao* in relation to the incidence of black-pod disease in Nigeria. *J. Ecol.* **40**, 125–142.

Thorold, C. A. (1952*b*). Air-borne dispersal of *Phytophthora palmivora*, causing black-pod disease of *Theobroma cacao*. *Nature, Lond.*, **170**, 718.

Thorold, C. A. (1953). The control of black-pod disease of cocoa in the western region of Nigeria. *Report of the Cocoa Conference* 1953, pp. 108–115. London: The Cocoa, Chocolate and Confectionery Alliance Ltd.

Thorold, C. A. (1954). The use of ultra-violet fluorescent substances for observations on dispersal of *Phytophthora palmivora* sporangia. *Nature, Lond.*, **174**, 409.

Vine, H. (1953*a*). Notes on the main types of Nigerian soils. *Spec. Bull. Agric. Dep., Nigeria*, no. 5. Lagos: Government Printer.

Vine, H. (1953*b*). Experiments on the maintenance of soil fertility at Ibadan, Nigeria, 1922–51. Part I. Introduction and review of the period 1922–33. *Emp. J. exp. Agric.* **21**, 65–85.

Waters, H. B. & Hunter, T. (1929). Measurement of rate of development of cacao pods. *Bull. Dep. Agric. Gold Cst* (*Year-Book*, 1928), **16**, 121–127.

West, J. (1936). Black-pod of cacao, experimental control on native farms. *Bull. Dep. Agric., Nigeria*, no. 11, 11 pp.

West, J. & Voelcker, O. J. (1942). Plantation cacao in the British Cameroons. *Trop. Agriculture, Trin.*, **19**, 4–11.

Williams, C. B. (1952). Comparing the efficiency of insect traps. *Bull. ento. Res.* **42**, 513–517.

Wright, J. (1930). A note on the saprophytic existence in Nature of *Phytophthora palmivora* (Butler), the causal organism of 'black-pod' disease of cacao. *Bull. Dep. Agric. Gold Cst* (*Year-Book*, 1930), **23**, 251–254.

EXPLANATION OF PLATE 16

Fig. 1. Longitudinal section of young fruit of *Theobroma cacao*, distal end. Showing depression at the tip, with mainly parenchymatous tissue below. The base of the style is shown within the tip cavity. (× 10.)

Fig. 2. Longitudinal section of young fruit of *T. cacao*, proximal end. Showing depression around the fruit stalk, with mainly fibro-vascular tissue below. (× 10.)

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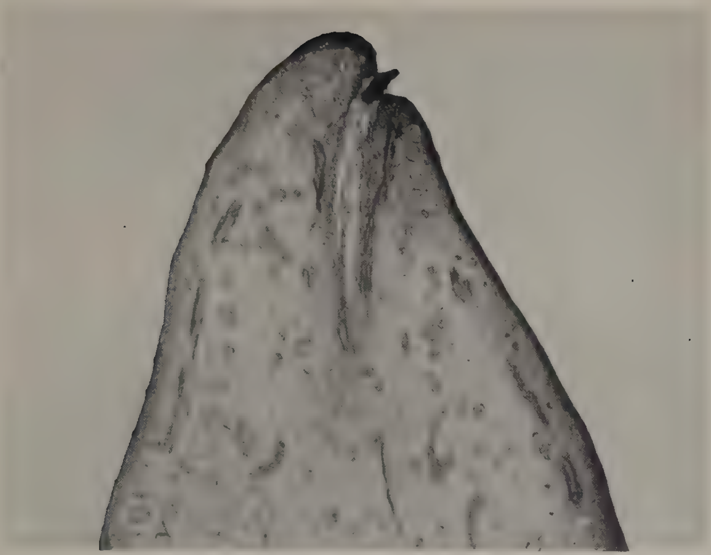

Fig. 1.

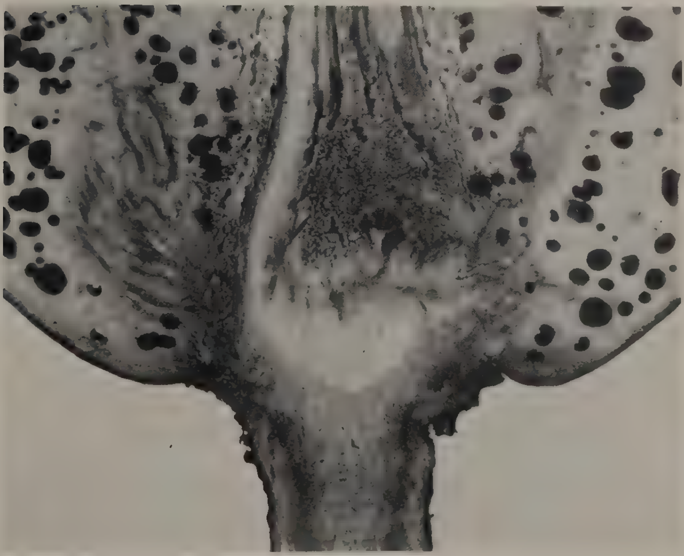

Fig. 2.

(*Facing p.* 452)

Trans. Brit. mycol. Soc. **38** (4) 453–464 (1955).

THE SPORE CONTENT OF AIR WITHIN AND ABOVE MILDEW-INFECTED CEREAL CROPS

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(With 3 Text-figures)

In addition to *Erysiphe*, the most abundant spores in the air in mildew-infected cereal crops were *Cladosporium*, *Alternaria*, *Sporobolomyces* and *Tilletiopsis*. On dry days *Sporobolomyces* and *Tilletiopsis* were most numerous at 04.00 G.M.T. and *Erysiphe*, *Cladosporium* and *Alternaria* at 16.00 G.M.T. *Sporobolomyces* predominated throughout wet days when *Alternaria* did not occur.

Between 12.00 and 16.00 G.M.T. on dry days, *Cladosporium* spores were the most abundant; their concentration increased progressively from April to July. *Erysiphe* conidia were few during April and May, and increased rapidly to a maximum in June; *Alternaria* was very rare until July. In smutted crops, *Ustilago* spores were also very rare in April and May but equally plentiful in June and July.

The spore concentration was always greater within than above the crop, when the spores were formed on the crop. More *Erysiphe* and *Cladosporium* spores occurred near the ground than at the top of the crop; there was little difference between the concentrations of *Ustilago*.

The date of sowing affected the spore concentrations; *Cladosporium* and *Sporobolomyces* were more numerous in an early- than in a late-sown wheat crop; the differences were least near harvest. *Erysiphe* conidia were more numerous in the late-sown crop.

Higher concentrations of *Cladosporium*, *Alternaria*, *Erysiphe*, *Sporobolomyces* and *Tilletiopsis* were found in a wheat crop given fertilizer (N, P and K) than in a crop given no fertilizer.

INTRODUCTION

The vertical distribution of spores in the air has been measured at heights of more than 30 m. above the ground, in studies dealing with the long-range movement of spores in air currents (Stakman, Henry, Curran & Christopher, 1923; Cragie, 1945), but little has been done at lower levels.

Vertical gradients in spore concentration within 2 m. of the spore source are described in this paper. Spores were trapped at different times and at different levels within and above cereal crops infected with *Erysiphe graminis* DC., the cause of powdery mildew, to measure how the time of day and season affects both the composition and gradients of the air-borne spore flora, or air 'spora' (Gregory, 1952).

SAMPLING METHODS AND SITES

Erysiphe conidia are a major component of the air spora in dry weather and their number in the air shows a diurnal periodicity with a maximum about 15.00 G.M.T. They are removed by rain, after which few occur in the air for some hours (Hirst, 1953). As the present investigation centred on *Erysiphe* conidia, unless otherwise stated spores were trapped between 12.00 and 16.00 G.M.T. on days on which no rain fell, 'dry days' which will be contrasted with rainy days. All times given are G.M.T.

Air at different levels above ground was sampled with a portable and manually operated volumetric spore trap designed by Gregory (1954). It consists essentially of an impactor unit joined by 2·5 m. of rubber tubing to a suction unit of a pump and its controls. The impactor unit was held in a movable clamp attached to a rod tapered to a spike at one end—the spike was pushed into the ground.

Before using the trap the impactor orifice was always put facing along the crops rows, and it was not operated for 2 min., to allow the crop to recover from the disturbance caused by introducing the impactor. Suction was then applied to draw air through a slit-shaped orifice. This impacts the air-borne particles on a sticky microscope slide, forming a band about 14 × 3 mm. nearly centrally placed on the slide.

The data given are the geometric means of at least two independent samples, in each of which air was sampled at the rate of 10 l./min. for 5 min. The spores, placed in 'generic' groups, were counted within traverses equally spaced across the long axis of the trace—the number and width of the traverses varying inversely with the density of spore deposit. The catch of spores was expressed as the number of spores per cubic metre of air and was not corrected for the efficiency of the trap. The trap's efficiency is probably high compared with that of the non-suction type of spore trap, e.g. vertical cylinder and horizontal slide, and varies at the most by a factor of only two with variations in external wind speed and particle size.

Samples were taken during April–August 1953 and 1954, in and above numerous crops, all of which were infected with mildew at some stage in their development. Some had loose smut also, but none was appreciably attacked by any other leaf parasite. Their cultivation details are:

(1) Winter-sown wheat, cv. Squarehead's Master 13/4, Broadbalk Field, Rothamsted Experimental Station (R.E.S.). Wheat has been grown continuously since 1843 on this field, which is divided into 18 strips receiving different fertilizers. Plots 3 and 8 only were sampled. Plot 3 has received no fertilizers since 1839; plot 8 is given yearly 3½ cwt./acre superphosphate, 2 cwt./acre sulphate of potash, 1 cwt./acre sulphate of soda and 1 cwt./acre sulphate of magnesia at drilling, and 6 cwt./acre sulphate of ammonia as a spring top dressing. Each plot is divided into 5 sections, one of which is fallowed every year. Only the first crop after fallow was sampled; that sown on 12 November 1952 was sampled in 1953 and that on 23 October 1953 was sampled in 1954.

(2) Winter-sown wheat, cv. Hybrid 46, Gravel Pit Piece Field, Norfolk Agricultural Station (N.A.S.). Two crops given the same fertilizers, one sown on 7 October 1953 (early-sown) and the other sown on 2 December 1953 (late-sown), were sampled in 1954.

(3) Spring-sown wheat, cv. Atle, Garden Plots section of Great Field, R.E.S. The crop sampled in 1954 was sown on 22 March 1954.

(4) Spring-sown barley, cv. Plumage Archer, Garden Plots section of

Great Field, R.E.S. In 1953, crops sown on 28 February and 22 April 1953 were sampled and in 1954 a crop sown on 8 April 1954 was sampled.

The generic groups were determined by spore characteristics. The term 'spore' in this paper includes both sexual and asexual structures. Most of the *Erysiphe* group probably belonged to *E. graminis* DC., and of *Ustilago* in barley to *U. nuda* (Jens.) Rostr., and in wheat to *U. tritici* (Pers.) Rostr.—the agents of loose smut. The spores of *Sporobolomyces* and *Tilletiopsis* were similar to the descriptions given by Derx (1930) and Nyland (1950), respectively. Although *Sporobolomyces* spores in bulk are pink, individually they appear colourless. Spores of *Bullera* (Derx, 1930), a colourless fungus similar to *Sporobolomyces*, may have been included in this group. However, *Bullera* was comparatively rare on winter- and spring-sown cereals (Last, 1955*a*).

THE SPORA

Air 14 cm. above the ground in the wheat crops on plots 3 and 8, Broadbalk Field, R.E.S., was sampled on four dates during May and June 1954, at 12 hr. intervals, viz. at 04.00 and 16.00. The mean concentrations for the two plots of the spore types known to have a source within the crop are given in Table 1—*Cladosporium*, *Alternaria*, *Erysiphe*, *Sporobolomyces* and *Tilletiopsis* all grow on either living or dead leaves, and *Ustilago* is liberated from the ears.

Table 1. *The mean spore content of air in the wheat crops on plots* 3 *and* 8, *Broadbalk Field*, *R.E.S.*, *at* 04.00 *and* 16.00 G.M.T. *on* 4 *dry days during May–June* 1954

(Spores per cubic metre of air. Air was sampled 11 cm. above ground-level.)

	Cladosporium	*Alternaria*	*Ustilago*	*Erysiphe*	*Sporobolomyces*	*Tilletiopsis*
04.00 G.M.T.	1200	0	30	30	36,000	140
16.00 G.M.T.	6500	40	90	130	150	0

The higher concentrations of all spores except those of *Sporobolomyces* and *Tilletiopsis* occurred at 16.00. These differences reflect the differences in the diurnal periodicity of the various spore types—maximal concentrations of *Cladosporium*, *Alternaria*, *Ustilago* and *Erysiphe* occur from 12.00 to 17.00 and of *Sporobolomyces* at 05.00 (Hirst, 1953). *Sporobolomyces* falls within Hirst's hyaline basidiospore group and is probably the major component. The concentration of each spore type varied greatly from day to day; the variations in *Sporobolomyces* can be readily related to weather.

When air was sampled while the crop was wet with dew at 04.00 on 11 May, the number of *Sporobolomyces* spores/m.^{3} was 53,000, whereas at 16.00 on the same day (a dry one) it was only 20. The difference between the catches at 04.00 and 16.00 was smaller when there was dew in the morning and when there was free moisture on the foliage in the afternoon, as on 27 June when 0·8 mm. of rain fell between 12.00 and 13.00. Then the concentrations were 7050 and 950 spores/m.^{3} at 04.00 and 16.00, respectively—a ratio for 04.00/16.00 catches of only 7·4 against 2650 on 11 May. The ratio of the catches at 16.00 on 27 May and 04.00 on 28 May, when the spore concentrations were 40 and 315,000, respectively, was even greater. At 04.00 the crop was wet with rain which fell from 21.00 to 24.00 on 27 May.

The differences between the mid-day catches in wheat and barley crops on wet and dry days resembled the differences between early morning and afternoon catches on dry days (see Table 2).

Table 2. *The spore content of air 14 cm. above ground-level in cereal crops on rainy and dry days*

(Spores per cubic metre of air)

	Cladosporium	*Erysiphe*	*Alternaria*	*Sporobolomyces*	*Tilletiopsis*
I. Wheat, Broadbalk Field, R.E.S. Means of Plots 3 and 8					
(*a*) Sampled 13.00 G.M.T., 5 July 1953 (dry day)	54,000	16,200	4,200	35	0
(*b*) Sampled 11.00 G.M.T. 6 July 1953 (rainy day)	25,900	7,300	0	129,500	98,500
II. Barley, Garden Plots, Great Field, R.E.S. Sown 22 April 1953					
(*a*) Sampled 16.00 G.M.T. 8 July 1953 (dry day)	300,000	76,000	7,000	14,500	30
(*b*) Sampled 11.00 G.M.T. 19 June 1953 (rainy day)	15,000	4,000	0	250,000	49,000

There is no essential difference between the data obtained from the wheat and barley crops. The air within the wheat crop was first sampled after a dry spell of 48 hr. but, subsequently, 0·69 mm. rain fell overnight (02.00–06.00 on 6 July), and the crop was wet when sampled for a second time at 11.00 on 6 July. The sample from barley on 19 June was taken soon after 10·41 mm. of rain had fallen (from 05.00 to 07.00 on 19 June), and that taken on 8 July was preceded by 48 hr. of dry weather. In both wheat and barley the higher concentrations of *Sporobolomyces* and *Tilletiopsis* occurred immediately after rain, whereas more of the other spore types occurred on dry days. *Tilletiopsis* was extremely rare on dry days, and *Alternaria* was never caught on wet days.

In addition to *Sporobolomyces* and *Tilletiopsis* many spores of other groups, tentatively identified as ascospores, were trapped when it was wet in the summer. Table 3 gives data for catches in two adjacent plots of wheat and barley (Garden Plots, Great Field, R.E.S.) on 12 August 1954, after 7·27 mm. of rain which fell from 04.00 to just before the start of trapping at 17.00. The spores of group A, which may belong to a *Leptosphaeria* of the *eustoma* group, and of group B, are shown in Fig. 1. Spores of group A, which are dematiaceous, are much less abundant in the wheat than in the barley, while those of group B, which are hyaline, are nearly equally abundant in both groups. The difference between the concentrations of *Tilletiopsis* spores within the wheat and barley reflects the different populations of this fungus on the foliage—*Tilletiopsis* was more abundant on the barley than on the wheat.

Spores of *Cladosporium*, *Alternaria*, *Erysiphe*, *Ustilago*, *Sporobolomyces* and *Tilletiopsis*, usually formed, from June onwards, at least 90 %, and sometimes as much as 99 % of the spora within the crop. At times fragments of dematiaceous hyphae, probably of *Cladosporium* and *Alternaria*, were abundant. At 15.00 on 8 July 1953, 23,000 fragments of hyphae/m.^{3} of air were trapped at 11 cm. above ground-level in a barley crop in strongly turbulent conditions.

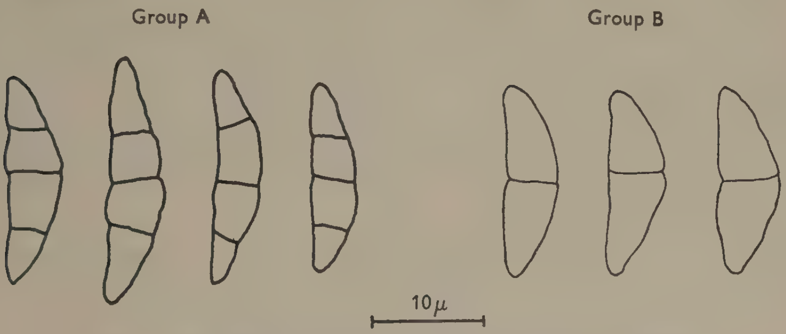

Fig. 1. Two unknown spore types present in high concentrations in wheat and barley crops following rain.

Table 3. *The spore content of air within and above spring-sown wheat and barley crops sampled* 16.36–17.42 G.M.T. 12 *August* 1954

(Spores per cubic metre of air. Site—Garden Plots, Great Field, R.E.S., 7·2 mm. rain fell from 04.00 to 16.00 G.M.T.)

	Cladosporium	*Alternaria*	*Ustilago*	*Erysiphe*	*Sporobolomyces*	*Tilletiopsis*	Group A	Group B
Barley—sampled 14 cm. a.g.l.*	1,100	190	190	430	68,000	810,000	68,500	69,000
Wheat—sampled 14 cm. a.g.l.	3,200	0	0	430	42,000	320,000	4,600	50,000
Mean concentration 180 cm. a.g.l.	1,200	20	70	0	3,800	1,800	400	1,600

* a.g.l. = above ground-level.

The effect of cultural treatments

The effect of date of sowing was tested in two wheat crops at Sprowston, N.A.S. Petri dishes, diameter 9 cm., containing 10 ml. of potato-dextrose agar were exposed at ground-level within the crops for 10 min. from noon, then incubated at 22·5° C. until the developing colonies were suitable for counting. The data from six sampling occasions are given in Table 4, each figure being the mean of ten replicates.

Table 4. *The mean number of* Cladosporium *colonies developed per Petri dish exposed at* 12.00 G.M.T. *in early- and late-sown winter wheat during* 1954 (*Sprowston*).

	Date of exposure					
	16 March	5 April	27 April	19 May	18 June	22 July
Early sown, 7 Oct. 1953	17·1	13·0	8·0	29·2	1,555	872
Late sown, 2 Dec. 1953	3·2	3·0	0·1	5·8	327	680
Mean	10·2	8·0	4·1	17·5	941	776

On all occasions, more *Cladosporium* colonies developed in the dishes exposed in the early-sown crop than in the late-sown; the difference was least on 22 July when both crops were at about the same stage of development, stage 11 (see Feekes scale, Large, 1954). Earlier the late-sown crop lagged behind the early-sown, e.g. on 5 April the early-sown crop was at stage 5 and the late-sown at stage 2. Comparable sets of Petri dishes were not exposed above the crop. The previous highest count of 336 *Cladosporium* colonies was for a 10 min. Petri dish exposure done outside Llandough Hospital, Cardiff on 11 August 1949 (Hyde & Williams, 1953). The mean daily count in their series of experiments did not exceed 100 colonies per dish even during the height of the *Cladosporium* season during any year's trapping from 1949 to 1953 inclusive (Hyde & Williams, 1953; Richards, 1954).

Table 5. *The distribution of* Sporobolomyces *colonies on the main stem leaf blades of early- and late-sown winter wheat sampled on* 17 *March* 1954

(*Sporobolomyces* colonies per sq.cm. of leaf blade.)

	Leaf number*						
	1	2	3	4	5	6	7
Early sown, 7 Oct. 1953	—	69·8 (Dead)	48·2	27·7	3·9	1·1	0·9
Late sown, 2 Dec. 1953	0·3	0·2	0·0	—	—	—	—

* Leaf 1 was the first to emerge, leaf 2 the second, and so on.

Sporobolomyces colonies, in addition to *Cladosporium*, developed on the agar but their numbers could not be estimated on 18 June and 22 July as they were too soon overgrown with *Cladosporium*. On the other four sampling occasions more *Sporobolomyces* colonies developed on the dishes exposed in the early-sown than in the late-sown crop, as with *Cladosporium*. 22·2 and 0·0 colonies developed per Petri dish exposed on 16 March, in the early- and late-sowings, respectively. This difference reflects the distribution of *Sporobolomyces* colonies on the leaf surfaces (Table 5) as determined by the method described by Last (1955*a*). The older leaves of the early-sown crop were heavily contaminated with *Sporobolomyces*, but the late-sown crop was almost free.

The concentration of *Erysiphe* conidia did not exceed 100/m.^{3} of air until June. On 18 June the concentrations were 14,000 and 860 for the late- and early-sowings respectively, and on 22 July they were 5300 and 2600. Thus on both occasions there were greater concentrations in the late-sown crop which was also the more heavily infected.

The effect of different fertilizer treatments on the composition of the spora within wheat crops is shown in Table 6. The air 14 cm. above ground-level was sampled in plot 3 (no fertilizer) and plot 8 (NPK) of Broadbalk Field, R.E.S., on both wet and dry days.

In dry conditions *Cladosporium*, *Alternaria* and *Erysiphe* predominated and were always more numerous within the crop on plot 8 than on plot 3. *Cladosporium* and *Alternaria* live on moribund tissue but *Erysiphe* is an obligate parasite. Although the increased plant density on plot 8 provides more substrata for the development of all three fungi and may also restrict air movements within the crop and so reduce the rate at which the spore cloud is diluted, the difference in concentration of *Erysiphe* spores is due mainly to the fertilizer increasing host susceptibility.

Table 6. *Comparison of the spore concentrations,* 14 *cm. above ground-level, in wheat crops differently fertilized on Broadbalk Field, R.E.S.*

(Plot 3 is not given fertilizer, plot 8 is given N, P and K. Spores per cubic metre of air.)

	Plot	*Cladosporium*	*Alternaria*	*Erysiphe*	*Sporobolomyces*	*Tilletiopsis*
		Dry days				
5 July 1953, 13.00 G.M.T.	3	24,000	400	350	20	0
	8	84,000	8,000	32,000	50	0
24 July 1953, 10.00 G.M.T.	3	109,000	3,200	610	230	40
	8	170,000	33,000	7,800	840	40
		Rainy days				
6 July 1953, 10.00 G.M.T.	3	6,900	0	40	22,100	40
	8	44,800	0	14,600	237,000	197,000
28 May 1954, 04.00 G.M.T.	3	680	0	0	140,000	0
	8	920	0	0	490,000	0

On rainy days, *Sporobolomyces* was consistently present in high concentrations, whereas *Tilletiopsis* occurred in the sample taken in July but not in May. Again the spore concentrations were greater within plot 8 than plot 3; the fertilizer most affected the concentrations of *Tilletiopsis* on 6 July 1953—40 spores/m.^{3} of air in plot 3 and 197,000 in plot 8. This difference may not be simply due to an effect of crop density but to variations in the suitability of the foliage for colonization by the fungus. *Alternaria* was absent from the air on both plots on rainy days.

Seasonal trends

From the series of samples taken on dry days during April to July 1954 inclusive, the concentrations of *Cladosporium*, *Alternaria*, *Erysiphe* and *Ustilago* within and above the crop, 14 and 180 cm. above ground-level respectively, were calculated (Table 7). The data are the means of samples

Table 7. *The mean spore content of air within and above five wheat and barley crops on dry days during April–July* 1954

(Spores per cubic metre of air.)

		April	May	June	July
Cladosporium	Within*	220	2,000	11,000	47,000
	Above	90	780	2,200	16,000
Alternaria	Within	<10	<10	80	510
	Above	<10	<10	<10	150
Erysiphe	Within	0	50	4,700	820
	Above	10	<10	540	240
Ustilago	Within	0	20	380	400
	Above	<10	20	320	270

* Within = 11 cm. a.g.l.; above = 180 cm. a.g.l.

taken in six crops—the two wheat crops, both at Sprowston and on Broadbalk Field, R.E.S., and the wheat and barley crops on the Garden Plots, R.E.S.

Usually spores were more concentrated within than above the crop. *Cladosporium* was on the average the most abundant of the four spore types, and the concentration of its spores progressively increased from month to month—an observation which agrees with those of Ainsworth (1952) and Richards (1954), who found the seasonal concentrations to be at a maximum from July to September. The seasonal trend was most pronounced in the early-sown wheat crop (Sprowston), where there were 380 spores/m.^{3} at 14 cm. above the ground on 19 May 1954, and 120,000 on 18 June 1954—the highest concentration recorded in 1954. The highest concentration recorded in 1953 was 304,000 spores/m.^{3}, 14 cm. above ground-level in a barley crop on 8 July.

Erysiphe and *Ustilago* were not abundant before June but subsequently increased; *Erysiphe* reached a peak in June, but *Ustilago* maintained almost the same concentration in June and July.

The level of mildew infection of the spring-sown barley crop (Garden Plots, R.E.S.) changed from 12·5 to 125·0 pustules per 100 cm.^{2} of main stem leaf blade from 25 May to 10 June 1954 (see Last, 1955*b*). This change in infection level was accompanied by a similar change in concentration of *Erysiphe* spores 14 cm. above ground-level, from 40/m.^{3} on 25 May to 100,000/m^3. on 15 June. Similarly, the spore concentration in the late-sown wheat (Sprowston) changed from 38/m.^{3} on 19 May to 14,000/m.^{3} on 18 June.

The increase in concentration of *Ustilago* spores is correlated with the emergence of ears infected with loose smut. At Sprowston, no smut spores were caught on 19 May but on 18 June, after the ears emerged, 29,000 spores/m.^{3} were detected. Subsequently, the concentration dropped to 1300 on 22 July. Similarly, the concentrations of *Ustilago*, 14 cm. above ground-level, in the 1954 barley crop (Garden Plots, R.E.S.) were 0, 230, 5200, 190 and 220 on 25 May, 15 June, 26 June, 19 July and 29 July, respectively. Ears started to emerge about 22 June.

Hyde & Williams (1946) found few *Alternaria* spores in the atmosphere except from June to September. Table 7 shows that the concentration of *Alternaria* in 1954 in the air both within and above the crop was less than 10/m.^{3} in April and May, but subsequently increased to a greater concentration within than above the crop. The highest concentration of *Alternaria* spores detected within a crop in 1953 was 36,000/m.^{3} at 10.00 on 24 July in the crop on plot 8, Broadbalk Field, R.E.S.; in 1954 the highest concentration was 5200/m.^{3} on 22 July, following 0 and 930 on 19 May and 18 June, respectively, within the late-sown wheat at Sprowston.

Vertical gradients of spore concentration

When the crop was providing a source of the spores, their concentrations within the crop were greater than in the air above. The ratio of spore concentration at 14 cm. above ground-level to that at 180 cm. above ground-level was not the same for all spore types and differed monthly.

The ratios for *Cladosporium* are 5·0 and 2·6, for *Erysiphe* 8·7 and 3·4 and for *Ustilago* 1·2 and 1·5 in June and July, respectively (Table 7).

The mean spore content of air, based on at least eight sets of observations, at the base, top and above a range of wheat and barley crops heavily infected or colonized with *Erysiphe*, *Cladosporium* and *Ustilago* are given in Table 8. The tops of the crops varied from 40 cm. to 88 cm. above ground-level.

Table 8. *The mean spore content of the air at the base, top and above a range of wheat and barley crops during June and July*

(Spores per cubic metre of air.)

	Base 11 or 14 cm. a.g.l.	Top 40 to 88 cm. a.g.l.	Above 180 cm. a.g.l.
Cladosporium	21,000	6,000	4,800
Erysiphe	6,000	1,300	610
Ustilago	3,400	3,200	2,400

The site where spores are liberated appears to determine the changes in spore concentration within the crop. *Ustilago* spores are liberated from the ears and were almost as abundant at the top as at the base of the crop; *Cladosporium* and *Erysiphe* spores are produced on the foliage lower in the crop and were more than three times as concentrated at the base as at the top of the crop.

The concentrations of *Erysiphe* and *Cladosporium* spores at two or more levels were determined within a range of crops, at least 70 cm. high. The spore concentrations are plotted in Fig. 2 (A and B) in arbitrary units which varied from one set of observations to another, on one date the unit being 1000 spores and on another 200 spores/m.^{3} Passing down a cereal stem there is first a zone of green leaves on which *Erysiphe* conidia may be produced and then at the base a mass of moribund tissue colonized by *Cladosporium*. The concentration of *Erysiphe* spores was usually greater at 40 cm., near their site of formation, than at 11 cm. above ground-level. Above 40 cm. to the top of the crop the concentration dropped steeply. The concentration of *Cladosporium* spores 40 cm. above ground-level, unlike that of *Erysiphe*, was never more than that at 11 cm. and the same only once, when the sampling was done in very turbulent air.

Table 9. *The changes in concentration of* Cladosporium *and* Erysiphe *spores at three levels within and one above a barley crop*

(Spores per cubic metre of air. Site—Great Field, R.E.S.; sampled 07.43–09.17 G.M.T., 26 June 1954).

	Sampling height above ground-level			
	14 cm.	42 cm.	82 cm.	180 cm.
Cladosporium	240,000	34,000	23,000	11,000
Erysiphe	11,000	16,000	3,000	1,000

Height of crop, 86 cm.

The steep drop in concentration of *Cladosporium* spores usually occurred between 11 and 40 cm. above ground-level. The differences in the distribution of *Cladosporium* and *Erysiphe* in a heavily infected barley crop on one

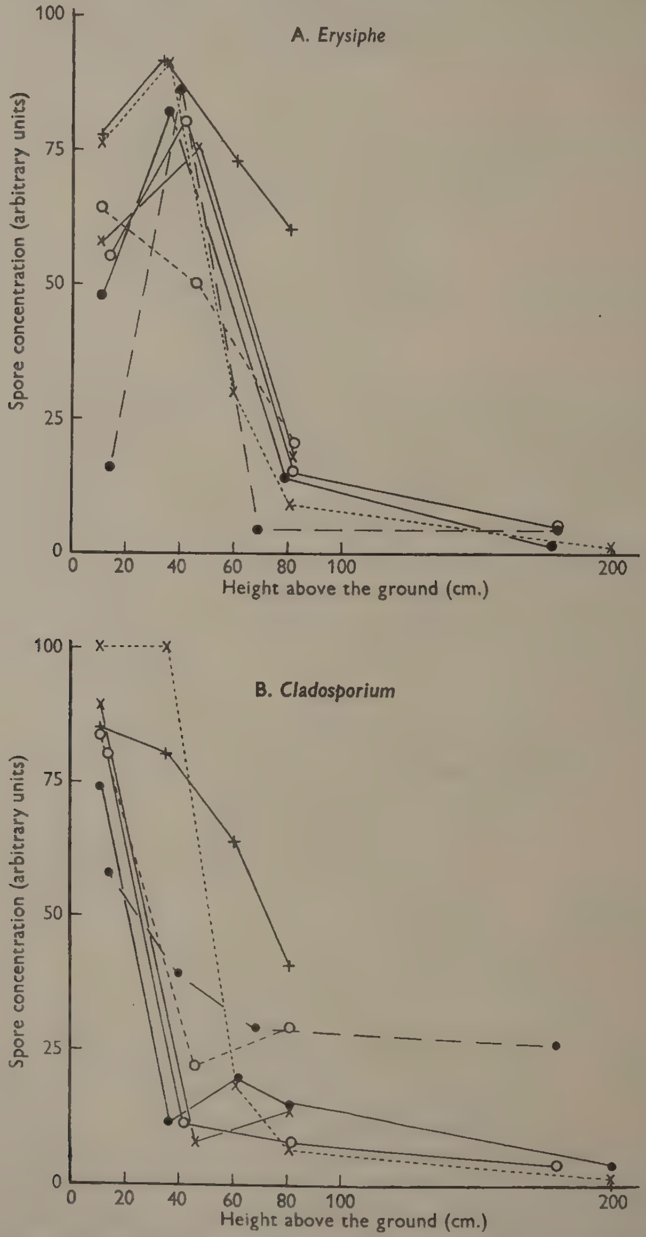

Fig. 2. The spore concentrations within and above wheat and barley crops at least 70 cm. high. A, *Erysiphe*; B, *Cladosporium*.

sampling occasion are shown in Table 9. The concentrations of *Cladosporium* at 14 and 42 cm. were 240,000 and 34,000, whereas those of *Erysiphe* were 11,000 and 16,000.

The changes in concentration of *Cladosporium* and *Erysiphe* spores from the top of the crop to a height of 180 cm. from ground-level were small compared with those within the crop (Fig. 2).

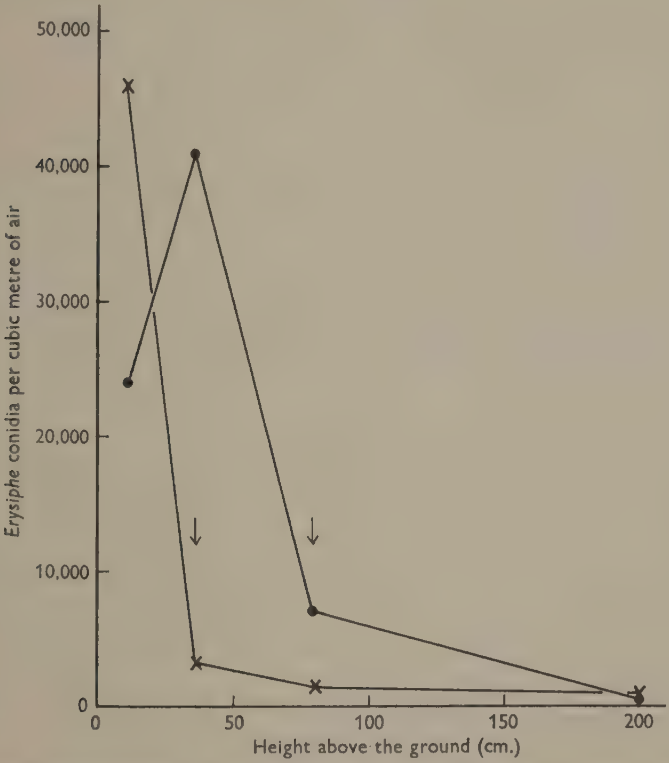

Fig. 3. The concentrations of *Erysiphe* conidia within and above two barley crops between 13.00 and 16.45 G.M.T. on 8 June 1953. ●——●, sown 28 February 1953; ×——×, sown 22 April 1953. ↓ = top of crop.

The changes in concentration of *Erysiphe* spores in two heavily infected and adjacent spring-sown barley crops, one 7 weeks older than the other, were measured on 8 June 1953 (Fig. 3). On the taller early-sown crop the concentration increased with height from 11 to 36 cm., and then rapidly decreased towards the top of the crop at 80 cm. The gradient in spore concentration from 36 to 80 cm. above ground-level in the older crop is similar to that in the late-sown crop from 11 to 36 cm.

DISCUSSION

There is a tendency for spore trapping to be done approximately 2 m. above the ground so that the catches may be correlated with meteorological factors—many of which are measured at this height. While the catches 2 m. above the ground are underestimates of the spore concentrations within the crop they undoubtedly reflect the changes with time in spore concentration within the crop. Their value as estimates of the concentration of inoculum to which the plants are exposed varies with the fungus.

When the spore concentration at the top of the crop is of interest, as in loose smut of cereals, the concentrations about 2 m. above the ground can be directly used as the two are nearly in equilibrium. However, the catches at 2 m. greatly underestimate the spore concentrations lower in the crop which are important in leaf diseases. Grainger (1954) found the concentration of *Helminthosporium aveneae* at the base of an infected oat crop was four times greater than that above the crop, whereas I found the ratios for *Erysiphe* and *Cladosporium* were 5·8 and 4·4, respectively. It is therefore impossible to use one factor, for all fungi, to convert the spore concentration above the crop into the concentration within the crop, as also it is impossible to use one conversion factor throughout the year for each spore type as the ratios vary from month to month, e.g. the ratios for *Erysiphe* are 8·7 in June and 3·4 in July (Table 7). These variations become more important when the concentration of inoculum and the amount of disease resulting from exposing a host to that quantity of inoculum are not simply related.

REFERENCES

AINSWORTH, G. C. (1952). The incidence of air-borne *Cladosporium* spores in the London region. *J. gen. Microbiol.* **7**, 358–361.

CRAIGIE, J. H. (1945). Epidemiology of stem rust in Western Canada. *Sci. Agric.* **25**, 285–401.

DERX, H. G. (1930). Étude sur les Sporobolomycètes. *Ann. mycol., Berl.*, **28**, 1–23.

GRAINGER, J. (1954). Spore production by *Helminthosporium avenae. Trans. Brit. mycol. Soc.* **37**, 412–419.

GREGORY, P. H. (1952). Spore content of the atmosphere near the ground. *Nature, Lond.*, **170**, 475–477.

GREGORY, P. H. (1954). The construction and use of a portable volumetric spore trap. *Trans. Brit. mycol. Soc.* **37**, 390–404.

HIRST, J. M. (1953). Changes in atmospheric spore content: diurnal periodicity and the effects of weather. *Trans. Brit. mycol. Soc.* **36**, 375–393.

HYDE, H. A. & WILLIAMS, D. A. (1946). A daily census of *Alternaria* spores caught from the atmosphere at Cardiff in 1942 and 1943. *Trans. Brit. mycol. Soc.* **29**, 78–85.

HYDE, H. A. & WILLIAMS, D. A. (1953). The incidence of *Cladosporium herbarum* in the outdoor air at Cardiff, 1949–50. *Trans. Brit. mycol. Soc.* **36**, 260–266.

LARGE, E. C. (1954). Growth stages in cereals. Illustrations of the Feekes scale. *Plant Path.* **3**, 129.

LAST, F. T. (1955*a*). Seasonal incidence of *Sporobolomyces* on cereal leaves. *Trans. Brit. mycol. Soc.* **38**, 221–239.

LAST, F. T. (1955*b*). Effect of powdery mildew on the yield of spring-sown barley. *Plant Path.* **4**, 22–24.

NYLAND, G. (1950). The genus *Tilletiopsis. Mycologia*, **42**, 487–496.

RICHARDS, M. (1954). Seasonal periodicity in atmospheric mould spore concentrations. *Acta allerg.* (*Kbh.*), **7**, 357–366.

STAKMAN, E. C., HENRY, A. W., CURRAN, G. C. & CHRISTOPHER, W. N. (1923). Spores in the upper air. *J. agric. Res.* **24**, 599–605.

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OBSERVATIONS ON THE INFECTION OF WHEAT BY LOOSE SMUT (*USTILAGO TRITICI* (PERS.) ROSTR.)

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(With Plates 17–20 and 3 Text-figures)

Loose smut is generally thought to enter the ovary by way of the style but a few workers have reported entry direct through the ovary-wall. There appears to be only one detailed account of the subsequent path of the fungus to the embryo, and this describes infection on the ventral (crease) side of the grain penetrating the scutellum at its base on the ventral side; all mycelium being described as intracellular.

The penetration of the fungus into the ovary and its subsequent passage to the embryo have been re-investigated. In 1953 and 1954 ears of three susceptible winter wheat varieties were inoculated at anthesis with loose smut. Ears were collected at intervals (6, 11, 18, 26 and 33 days), fixed, and the path of infection followed. Observations on the grain development were also made. Mycelium present on the surface of the ovary wall penetrates through the ovary wall (pericarp), traverses the parenchyma of the pericarp, and after about 11 days has entered the integuments (testa) and nucellus region. It permeates this region and passes towards the base of the grain. The fungus enters the aleurone layer but only rarely penetrates the endosperm. On the dorsal side of the grain, the fungus grows from the testa, nucellus and aleurone layers to the scutellum (after about 26 days). The mycelium grows profusely in the scutellum and passes to the growing point of the embryo. It has not been found in the plumule and radicle.

In 1954 ears were also collected from an infected commercial crop of Hybrid 46 and grains from these ears were examined. The fungus had penetrated directly through the ovary-wall and the general internal location of mycelium was exactly as in artificially inoculated grains.

No trace of infection via the style has been seen and mycelium present on the ventral side of the grain has not been found to enter the scutellum.

Mycelium is mainly intracellular in the pericarp and testa, and mainly intercellular in the aleurone, scutellum and other tissues of the embryo. The actual penetration through the epidermis of the ovary-wall is very similar to that described for other smut diseases. Appressoria are formed over the points of penetration, funnel-like structures are present, and considerable sheathing of internal mycelium is seen. Numerous peg-like structures are present on the mycelium in the testa.

INTRODUCTION

Floral infection of wheat by *Ustilago tritici* (Pers.) Rostr. was first practically demonstrated by Maddox (1896). Brefeld (cf. McAlpine, 1910) published a series of experiments in which loose smut spores were dusted on to the stigmas of wheat flowers. The resulting seeds were sown and the plants were heavily infected. McAlpine (1910) suggested that, in addition to stigma penetration, the fungus may penetrate the young ovary-wall. Lang (1910) has given the fullest account of the disease, both of its manner of entry into the ovary via the stigma and also of its subsequent path to the embryo proper.

Freeman & Johnson (1909), in America, stated that the spores come in contact with the young ovary-wall or the stigma, and after germination the fungus penetrates the ovary-wall. Later, Ruttle (1934) observed mycelium growing through the ovary-wall in several places. More recently, Vanderwalle (1942) confirmed Lang's suggestion that desiccation of the fine terminal ramifications of the stigma favoured penetration, but was not able to demonstrate a direct passage of hyphae into the style. However, he also found mycelium in the lower half of the ovary which had no connexion with mycelium towards the top and was able to establish 'absolutement certaine et irrefutable' the presence of penetration points at the base of the ovary.

With these conflicting reports in the literature it was decided to reinvestigate the path of infection (see Batts (1955*a*) for a preliminary account).

MATERIALS AND METHOD

In 1953 and 1954 ears of susceptible winter-sown wheat varieties (Vilmorin 27, Hybrid 46 and Bersee) were inoculated at anthesis in the field by the partial vacuum method (Moore, 1936; Oort, 1939). A number of ears were picked at intervals (6, 11, 18, 26 and 33 days) after inoculation, fixed in formalin–acetic–alcohol, and subsequently kept in 50 % alcohol. Grains were then examined by two methods:

(*a*) *Surface preparations.* The various parts of the grain, pericarp, testa and embryo were separated and stained in cotton blue in lactophenol. Well over 100 grains have been examined by this method.

(*b*) *Microtome sections.* Serial microtome sections, 12 μ thick, were prepared and stained in Carbol Thyanin Blue counterstained with Orange G. About a dozen infected grains have been examined in this way.

On 20 July 1954 ears were picked from a field of rather severely infected Hybrid 46 in Sussex. They were brought to the laboratory and fixed and preserved as before. Grains from these ears have been examined by method (*a*) above.

DEVELOPMENT OF THE WHEAT GRAIN

Before investigating the disease the development of the grain must be understood. Detailed accounts are available (Percival, 1921; Hector, 1936). A useful summary may be found on page 119 of Hector's book and this nomenclature is followed.

RESULTS FROM ARTIFICIAL INOCULATIONS

The observations made on the 1953 material were entirely confirmed the following year, the path of infection was the same in the three varieties and all results are treated together.

After 6 *days* the ovary had begun to swell but it was still very small (approx. 3·0 mm. long × 2·5 mm. broad × 2·0 mm. thick), and still somewhat heart-shaped. The stigma branches were quite turgid and very much in their fresh condition. Hairs (the brush) were plentiful over the top of the ovary. The integuments surrounding the developing endosperm and embryo occupied a very small proportion of the grain. Very little obvious cell differentiation was apparent, cells were thin walled, full of protoplasm and were deeply stained by cotton blue.

Spores were plentiful over the stigma, brush and ovary-wall, and germ tubes were present. It was not possible to decide whether a spore had germinated or not unless the germ tube was still attached, because germinated spores retain the brown wall coloration. No entry of the fungus could be found, although this would not be easy to demonstrate because of the deep staining of the host cells.

After 11 *days* considerable development had taken place in the ovary (now approx. 5·5 × 3·0 × 2·5 mm.). The endosperm surrounded by the developing testa (derived from the integuments) was a narrow elongated area occupying the middle third of the grain. The cells of the outer integument had disappeared and the cells of the outer layer of the inner integument were still full of contents. Over this layer a cuticle was developing. Pigment was being deposited in the cells of the inner layer of the inner integument (the future coloured layer of the testa) but as yet it was globular in appearance. The cells of the nucellus were in the main discernible, and the future aleurone cells surrounding the endosperm were elongated and very thin walled. The cells of the pericarp contained starch grains and were mainly thin walled, but thickening had begun. The embryo was lenticular in shape having about twenty cells across its widest point. The coleoptile showed as a small projection.

Mycelium was present on the outside of the pericarp, and there were numerous points of penetration through the ovary-wall. Mycelium in the pericarp was mainly intracellular. The actual manner of penetration and general host-parasite relationships are discussed later. Infection may be present in almost any part of the pericarp, but the most frequent position was on the shoulders just beneath the lowest of the hairs. No mycelium was seen at the apex of the grain, i.e. in the area of the style. The fungus was usually found to have crossed the pericarp in a centripetal direction and entered the developing testa and nucellus.

After 18 *days* the size of the grain was approximately 7·5 × 3·0 × 3·0 mm. Considerable expansion of the endosperm had occurred and it now occupied about three quarters of the grain. More pigment was present in the cells of the inner layer of the inner integument, and the cuticle was now immediately to the outside of the layer, the cells of the outer layer having been compressed. The nucellus cells were discernible in some surface preparations and the aleurone cells were still somewhat elongated but were beginning to thicken. The pericarp was considerably reduced and cell thickening was proceeding, the future cross-layer cells still retaining their contents. In the embryo the plumule and root initials were visible and the coleoptile was present as a distinct projection over the plumule initials.

Penetration points were plentiful and intracellular mycelium was present in many parts of the pericarp. Stomata were present on certain areas of the pericarp, but the fungus has not been found to enter through them. The fungus was present to some extent in the young aleurone and was permeating parts of the testa-nucellus region where the fungus grew towards the base of the grain. Hyphae rarely penetrated the endosperm.

After 26 *days* the host development was in general only a little behind that at 33 days, and a detailed description is given then. This material was examined as surface preparations only.

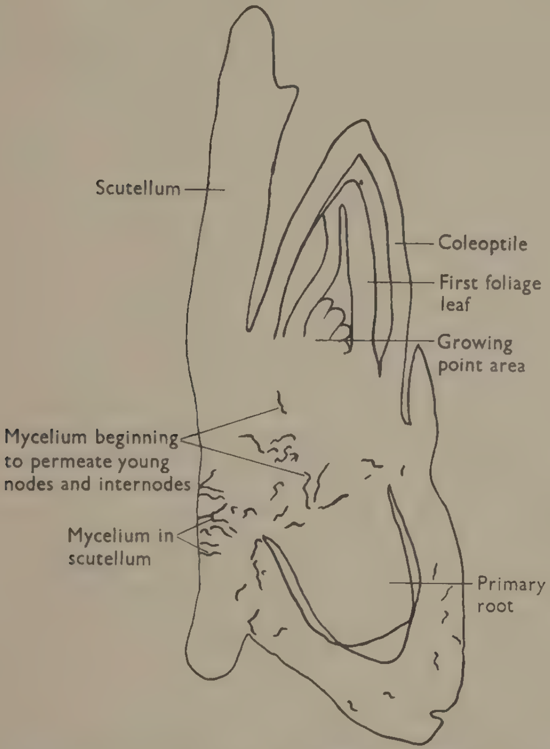
Mycelium was plentiful on the outside of the pericarp with obvious penetration points. Parts of the coloured layer of the testa were heavily infected and invagination of the cell contents by peg-like processes was frequently seen. In about 20% of the grains examined, mycelium had reached the scutellum, and it seems, therefore, to be approximately the earliest stage at which this occurs. If, by chance, infection entered the base of the grain in the region of the embryo, it is probable that mycelium would enter the scutellum sooner, but entry is most common on the shoulders of the grain.

After 33 *days* very considerable development of the grain had taken place and it was approaching its mature form. The grain was approximately 8·0 × 3·5 × 3·0 mm. Almost the whole of the grain was occupied by starch-filled endosperm cells. Except in the chalazal (crease) region the testa cells were compressed into a very narrow band on the inside of the pericarp, the inner layer being completely pigmented, and it now appeared as at maturity (Pl. 17, figs. 2, 3; Pl. 18, fig. 1). On the chalazal side the testa was continued as a layer about four cells wide. The aleurone cells were still fairly thin walled but less rectangular in shape (Pl. 17, fig. 3). The nucellus was a narrow structureless mass between the testa and aleurone (Pl. 17, fig. 3). The pericarp, with typical beaded thickening in the cell walls, was nowhere more than 3–4 cells wide, being rather more compressed on the dorsal side. The embryo was well developed, plumule and radicle differentiation being advanced (Pl. 18, fig. 2).

It is at this stage that the whole path of development of the fungus can be followed. Mycelium and penetration points were easily found on the pericarp (Pl. 17, fig. 1). Mycelium was found occasionally in the remaining parenchyma cells of the pericarp. Certain areas of the testa were often completely permeated with mycelium which was mainly intracellular and numerous peg-like processes invaginated the contents of the coloured layer (Pl. 17, fig. 2). Hyphae were occasionally found associated with the aleurone cells, but the endosperm was rarely penetrated and then only to a depth of a few cells (Pl. 17, fig. 3). The direction of growth of the mycelium in the testa region was towards the base of the grain, perhaps being attracted by the concentration of food materials. On the dorsal side of the grain the fungus passed from the testa over the aleurone to the scutellum (Pl. 18, fig. 1). The fungus developed extensively in the scutellum and penetrated the embryo proper (Pl. 18, fig. 2), but infection was not found in the plumule or radicle (Text-fig. 1).

OBSERVATIONS ON EARS FROM A COMMERCIAL CROP

The grains were on average 7·5 × 4·5 × 3·5 mm., the stage of growth being approximately 5 weeks after anthesis, the structure being similar to that described for 33 days. Of about fifty grains examined two were infected. In these the embryo was infected, mycelium was plentiful in the testa, with scattered bits in the aleurone. Spores, mycelium and penetration points were plentiful on the pericarp. Spores were also present on the stigma (which still showed much of its original structure), together with numerous pollen grains.



Text-fig. 1. Diagrammatic representation of mycelium in embryo (L.S.), built up from serial microtome sections of one infected grain; 33 days after inoculation.

Grains from a partially infected ear were also examined, the lower third of the ear being infected. Eleven grains were examined from this ear and five were infected, mycelium being present as above. Penetration points were easily found.

The distribution of mycelium in the naturally infected grain was therefore identical with that found after artificial inoculation, and there is no reason to expect that the path of infection would be different in any way.

The tissues of the rachis of the partially infected ear were also examined. Mycelium was plentiful in the lower third, i.e. in the portion carrying the diseased spikelets but no mycelium was found above this.

Discussion on path of infection

The observations made on the infection of wheat by loose smut do not confirm the original descriptions. The usually accepted story has been passage of the fungus down the style, but no detailed description has been found in the literature. Lang's illustration, which has frequently been copied by authors of text-books etc., is reproduced in Text-fig. 2. It indicates very little. Vanderwalle (1942), although observing penetration through the ovary-wall, considered that infection also took place via the style, and supported Lang in considering that desiccation of the stigma branches 3 days after infection favoured penetration. In the varieties studied, the stigma does not alter substantially for a week or two after anthesis. As with Lang, Vanderwalle gave no details of passage of the fungus down the style and into the top of the ovary.

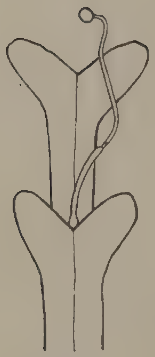


Fig. 2.

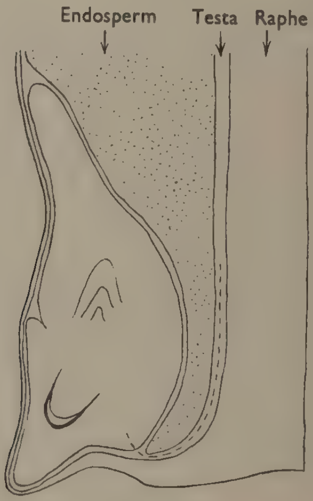


Fig. 3.

Text-fig. 2. A germ tube attempting to penetrate between the papillae of turgid stigmatic lobes of wheat flower. (After Lang, 1910.)

Text-fig. 3. Entry of mycelium into scutellum on ventral side between endosperm and testa. (After Lang, 1910.)

The only account of the path of infection from inside the ovary-wall to the embryo is that of Lang (1910). His diagrammatic representation is given in Text-fig. 3. Lang described the mycelium growing on the ventral side in the intercellular spaces of the two layers of the inner integument (testa). He did not observe penetration into the endosperm. After about 3 weeks the mycelium had reached the lower end of the raphe and it then curved round towards the dorsal side between the endosperm and testa and reached the lower end of the scutellum and penetrated its tissues. In the present investigation, mycelium has been frequently seen on the ventral side of the grain, but it has not been found to lead to infection of the scutellum and embryo. If Lang's theory was correct mycelium would enter the scutellum at its lowest ventral projection and be most concentrated there. In the embryos examined, no mycelium has been found in this position (Pl. 18, fig. 2, Text-fig. 3).

Although Ruttle (1934) examined two grains only of susceptible varieties her results are largely in agreement with those here described. Thus, in Honor wheat fixed 14 days after inoculation, 'at various points along the ovary wall mycelium was observed growing in from the surface where there were spores directly through the ovary wall cells at right angles to their longitudinal axis'. Mycelium was abundant in the ovary wall. A little was present in the aleurone but none in the embryo and endosperm. In Reward wheat 22 days after inoculation mycelium was abundant, not only in the pericarp but also in the aleurone, outer layers of endosperm, scutellum, hypocotyl, and even root primordia of the embryo. Infection was therefore considerably advanced in Reward wheat after 22 days. At Cambridge, 11 days after this, mycelium was only beginning to permeate the embryo proper. However, Reward was grown as an early maturing spring wheat (Clark, 1930) and development would be rather quicker than in winter wheat grown in England.

Infection can take place over a period of a fortnight or more, i.e. from pre-anthesis until post-anthesis (Batts, 1955*b*). It is probably a stage in the development of the thickening of the epidermis of the pericarp which arrests further infection by germinating spores. Lang considered that the development of the cuticle on the integuments (testa) was the feature responsible for stopping infection. This cuticle has been seen to act as a barrier to the fungus, but whether the thickening of the epidermis of the pericarp or this cuticle primarily acts as a barrier to further infection has not been determined.

With the method of inoculation adopted, a fairly heavy concentration of spores is introduced into the inoculated ears, and it would not be unreasonable to question whether it was only under these conditions that infection would take place through the ovary-wall. It would not, however, be expected to exclude infection via the style if that was the natural route, but, if anything, it would be in addition to infection via the style. However, no trace of infection via the style has been found in any inoculated or naturally infected grain.

PRESENCE OF OTHER FUNGI

Invasion of the pericarp by secondary moulds (Hyde & Galleymore, 1951) was sometimes found. When present it was sometimes visible to the naked eye and such grains were not used for investigation. The mycelium of the secondary fungi was usually restricted to the pericarp, but as reported by Ruttle (1934) parts of the testa were occasionally infected also. As found by Hyde & Galleymore, infection was only present during the later stages of development. Mycelium of other fungi, particularly *Cladosporium* sp., was very frequently seen on the stigma branches.

HOST PARASITE RELATIONSHIPS

Very little attention has previouly been given to the host parasite relationships between *Ustilago tritici* and wheat. Lang & Vanderwalle reported that mycelium was entirely intercellular. Ruttle found mycelium 'ramifying within and between the ovary wall cells'.

In the present studies, mycelium was mainly intracellular in the pericarp and testa (Pl. 17, fig. 2; Pl. 19, figs. 1, 2), and mainly intercellular in the aleurone, scutellum, and other tissues of the embryo (Pl. 17, fig. 3; Pl. 18, figs. 1, 2).

Intracellular mycelium has frequently been reported in other smuts, e.g. *Ustilago avenae* (Kolk, 1930; Western, 1936), *U. maydis* (Walter, 1934), *Urocystis occulta* (Ling, 1940), *Tilletia caries* (Woolman, 1930).

PENETRATION

Very little information regarding the penetration of the fungus is available in the literature. The germ tubes were said to enter the stigma only when its branches had begun to collapse. Thereafter, the fungus was said to follow the channels left by pollen tubes.

In the present work, the only mode of entry seen has been directly through the ovary wall. Penetration appears to be possible through any part of the epidermis. It is sometimes between the vertical walls of the epidermal cells but very often through the centre of the cell-wall (Pl. 20, fig. 2). Some swelling and staining of adjacent cell-walls usually occurs. At the point of entry, an appressorium is formed which stains deeply in cotton blue. Beneath the appressorium a bulbous swelling develops through which the penetrating hypha passes in a narrowed condition, and a funnel-like structure results (Pl. 19, figs. 1, 2). In the formation of these funnels, the reaction of the host appears to be such that the cuticle and cell-wall is invaginated. The structure of the funnel is not homogeneous, but approximately in the centre of each side of the funnel is a somewhat darker area (Pl. 19, fig. 1), which as far as can be judged is the space between the cuticle and cell-wall. Nearer the surface of the funnel the cuticle is separated even further from the cell-wall. The ring around the penetration tube where the greatest separation of cuticle from cell-wall has taken place usually becomes stained (Pl. 20, fig. 4). The presence of the fungus appears to activate the host in such a way that the funnel structure develops as a continuation of the invaginated cuticle and cell-wall. Once the mycelium has passed through the funnel it assumes its normal diameter. Sheathing of the internal mycelium is extremely common (Pl. 19, figs. 1, 2; Pl. 20, fig. 4).

Mycelium is intracellular in the pericarp. An appressorium is formed over each wall at the point of penetration, the appressoria sometimes being rather large (Pl. 19, fig. 3). Sheathing is often present around the appressorium. The wall adjacent to the appressorium begins to swell and takes up stain. An early stage in the formation of the appressorium is a foot-like process at the tip of the advancing hypha. The cell-wall in contact with the foot swells and takes up stain (Pl. 20, fig. 1). A small peg-like projection is formed beneath the appressorium and the cell-wall continues to swell around this projection (Pl. 19, fig. 3). The projection gradually enlarges and finally it passes into the cell (Pl. 20, fig. 4). The hole formed in the cell-wall by the penetrated hypha is clearly shown in Pl. 20, fig. 3. In older material, diamond-shaped structures remain at the points of penetration through successive cell walls (Pl. 19, figs. 1, 2).

In the testa the mycelium passes in and out of the cells with apparently very little difficulty, even slight construction of the mycelium as it passes through a cell-wall is rarely seen. Interesting features of the mycelium in the testa are the way in which it meanders through the pigmented layer, and the presence of numerous lateral projections which invaginate the pigmented cell contents.

DISCUSSION

The funnels which are present at the point of entry of the fungus are extremely similar to those described for other smut fungi (*Urocystis cepulae* Anderson, 1921; *Ustilago avenae* Western, 1936; *Urocystis occulta* Ling, 1940). Anderson suggested that the funnel was an inward growing sheath of wall material and that it was possible that the wall of the infection hypha might thicken and take part in the formation of the tube. Ling, on the other hand, thought that the infection hypha pushed the epidermal cell-wall of the rye coleoptile inward to form a large deep cavity. Yet another explanation (Lutman, 1910) suggested that layers of wall material were deposited, the invading hypha dissolving its way through them until finally a funnel-shaped tube of host wall material was present about the infection hypha. Fellows (1928) describing infection of wheat by *Ophiobolus graminis* reports structures similar to the funnels, which he calls 'lignitubers'. A protuberance develops on the cell-wall opposite the point of infection which elongates at right angles to the wall, extending in front of the hypha as it advances, the hypha becoming more and more attenuated. Finally, either the hypha is able to outgrow the protuberance and enter the cell, or the protuberance is able to prevent it. The hypha assumes its normal size once it emerges from the protuberance.

In wheat the presence of *Ustilago tritici* appears to cause softening of the cell-wall which is then invaginated. On no occasion has the host thickening been seen to arrest penetration. It has been suggested that these thickenings are evidence of a resistance in the host, but their presence in the three susceptible varieties investigated would hardly support that view.

Sheathing of the mycelium of smut fungi has frequently been reported, and according to Rice (1927) it is characteristic of many Ustilaginales. The diamond-shaped structures produced in the cell-walls by the intracellular mycelium in the pericarp are extremely similar to those found in *U. avenae* (Kolk, 1930).

CONCLUSIONS

The observations presented here throw new light on the infection of wheat by *U. tritici*. Many of the features described are new for the species, but they are entirely in keeping with results obtained by workers on other smuts. In general, the smut fungi can enter the host only at points where the tissue is relatively young, and in the case of loose smut, it enters the ovary-wall.

The general effects of the fungus on the wheat cells are very similar to those described for many other smut diseases. It is rather unlikely that hyphae of such a fungus could enter wilting stigmas only and then find it necessary to follow spaces left by pollen tubes in order to reach the embryo.

In the large number of grains examined infection has always been found to enter through the ovary-wall, and entry of the fungus into the scutellum and embryo has always been found to be from the dorsal side.

I am sincerely grateful to Mr W. C. Stigwood of the Botany School, Cambridge, for cutting and staining the microtome sections; to Dr S. Dickinson for helpful discussion; and to my assistant, Mrs R. S. L. Jeater, for general assistance throughout the work. I also wish to thank Mr M. W. Jolley for taking the photographs.

REFERENCES

Anderson, P. J. (1921). Development and pathogenesis of the onion smut fungus *Tech. Bull. Mass. agric. Exp. Sta.* no. 119, 34 pp.

Batts, C. C. V. (1955*a*). Infection of wheat by loose smut *Ustilago tritici* (Pers.) Rostr. *Nature, Lond.*, **175**, 467.

Batts, C. C. V. (1955*b*). Loose smut *Ustilago tritici* (Pers.) Rostr. of wheat. Physiologic specialization and reaction of varieties in England. *Ann. appl. Biol.* (in the Press).

Clark, J. A. (1930). Varieties of hard red spring wheat. *Fmrs' Bull. U.S. Dep. Agric.* no. 1621, 25 pp.

Fellows, H. (1928). Some chemical and morphological phenomena attending infection of the wheat plant by *Ophiobolus graminis*. *J. agric. Res.* **37**, 647.

Freeman, E. M. & Johnson, E. C. (1909). The loose smuts of wheat and barley. *Bull. U.S. Bur. Pl. Ind.* no. 152, 48 pp.

Hector, J. M. (1936). *Introduction to the botany of field crops*. Vol. I. *Cereals*. 478 pp. Johannesburg: Central News Agency.

Hyde, M. B. & Galleymore, H. B. (1951). The subepidermal fungi of cereal grains. II. The nature, identity and origin of the mycelium in wheat. *Ann. appl. Biol.* **38**, 348.

Kolk, L. A. (1930). Relation of host and pathogen in the oat smut, *Ustilago avenae*. *Bull. Torrey bot. Cl.* **57**, 443.

Lang, W. (1910). Die Blüteninfektion beim Weizenflugbrand. *Zbl. Bakt.* (2. Abt.), **25**, 86.

Ling, L. (1940). The histology of infection of susceptible and resistant selfed lines of rye by the rye smut fungus, *Urocystis occulta*. *Phytopathology*, **30**, 926.

Lutman, B. F. (1910). Some contributions to the life history and cytology of the smuts. *Trans. Wis. Acad. Sci. Arts Lett.* **16**, 1191.

Maddox, F. (1896). Eastfield experiments. Smut and bunt. *J. Coun. Agric. Tasmania*, **4**, 92.

McAlpine, D. (1910). *The smuts of Australia*, 288 pp. Melbourne.

Moore, M. B. (1936). A method for inoculating wheat and barley with loose smuts. *Phytopathology*, **26**, 397.

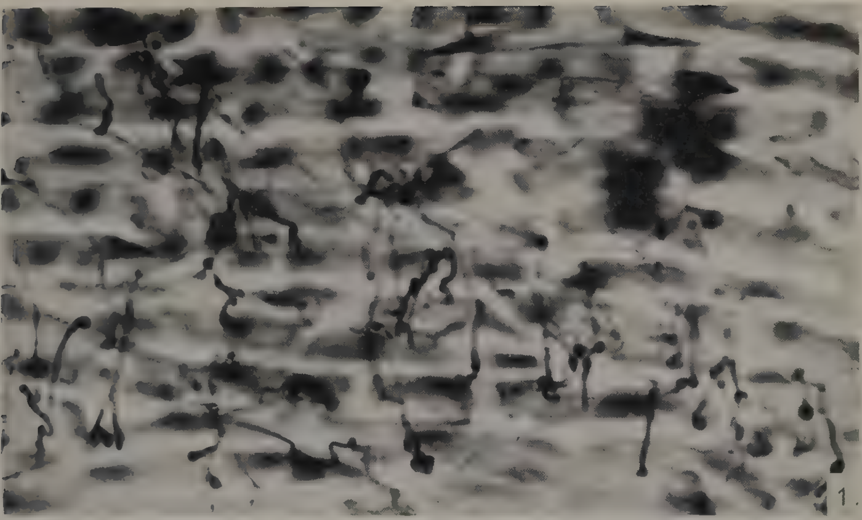
Oort, A. J. P. (1939). Inoculation experiments with loose smuts of wheat and barley. *Phytopathology*, **29**, 717.

Percival, J. (1921). *The wheat plant. A monograph*, 463 pp. London: Duckworth and Co.

Rice, M. A. (1927). The haustoria of certain rusts and the relation between host and pathogen. *Bull. Torrey bot. Cl.* **54**, 63.

Ruttle, M. L. (1934). Studies on barley smuts and on loose smut of wheat. *Tech Bull. N.Y. agric. exp. Sta.*, no. 221, 39 pp.

Vanderwalle, R. (1942). Note sur la biologie d'*Ustilago nuda tritici* Schaf. *Bull. Inst. agron. Gembloux*, **11**, 103.



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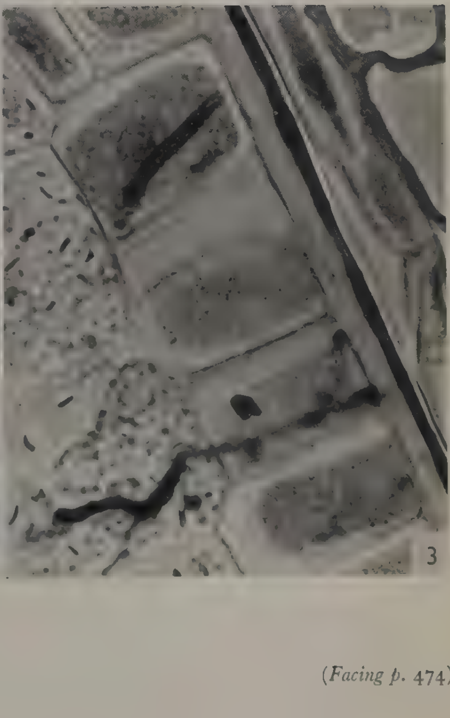

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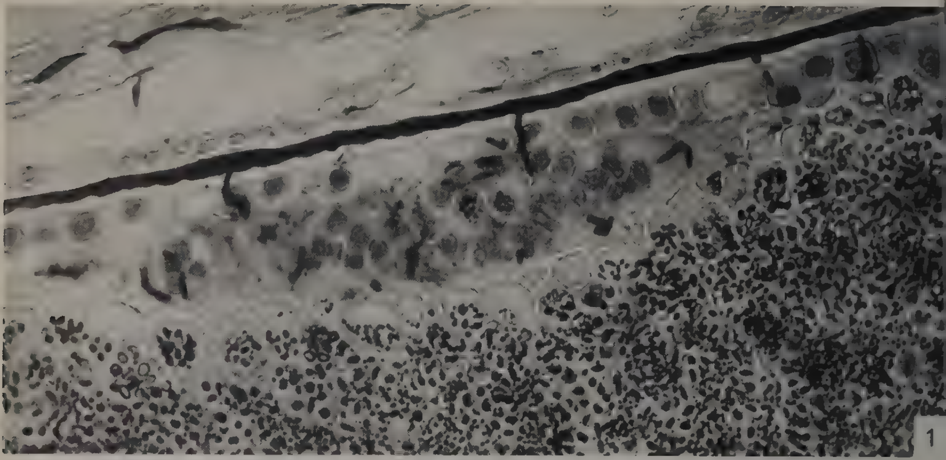
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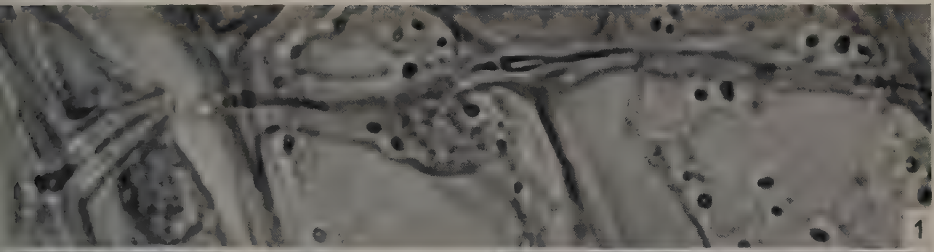

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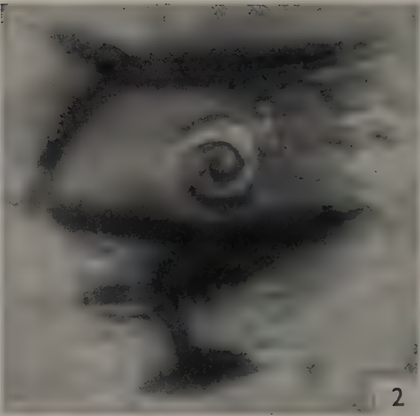
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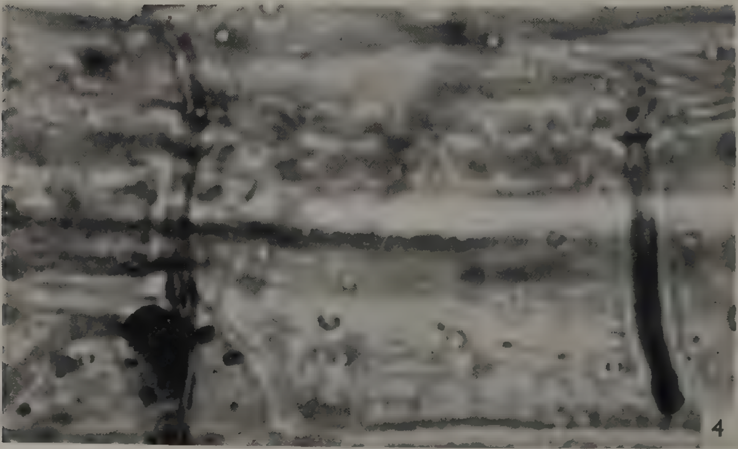
4

WALTER, J. M. (1934). The mode of entrance of *Ustilago zeae* into corn. *Phytopathology*, **24**, 1012.

WESTERN, J. H. (1936). The biology of oat smuts. IV. The invasion of some susceptible and resistant oat varieties, including Markton, by selected biological species of smut (*Ustilago avenae* (Pers.) Jens. and *Ustilago Kolleri* Wille). *Ann. appl. Biol.* **23**, 245.

WOOLMAN, H. M. (1930). Infection phenomena and host reactions caused by *Tilletia tritici* in susceptible and non-susceptible varieties of wheat. *Phytopathology*, **20**, 637.

EXPLANATION OF PLATES 17–20

PLATE 17. 33 days after inoculation.

Fig. 1. Mycelium of *Ustilago tritici* on pericarp of wheat with appressoria and penetration points. × 200.

Fig. 2. Surface preparation of testa with intracellular mycelium. Note peg-like projections. × 900.

Fig. 3. L.S. grain with mycelium in aleurone layer and hypha penetrating endosperm. × 660.

PLATE 18. 33 days after inoculation.

Fig. 1. L.S. grain near edge of scutellum with mycelium entering scutellum from testa. × 780.

Fig. 2. L.S. through centre of embryo with mycelium in scutellum and beginning to enter cells of embryo proper. × 42.

PLATE 19. Fig. 1, 18 days after inoculation;
Figs. 2 and 3, 26 days after inoculation.

Fig. 1. L.S. pericarp with funnel at point of entry and sheathing of intracellular mycelium. × 1350.

Fig. 2. Surface preparation of pericarp with funnel and sheathing as in fig. 1. × 1125.

Fig. 3. Surface preparation of pericarp with appressoria and stages in penetration of walls by intracellular mycelium. × 1125.

PLATE 20. Figs. 1, 2 and 4, 26 days after inoculation;
Fig. 3, 18 days after inoculation.

Fig. 1. Surface preparation of pericarp with foot-like process at tip of hypha prior to penetration of cell-wall. × 750.

Fig. 2. Surface preparation of pericarp with penetration through centre of cell-wall, and thickening of adjacent cell-walls. × 1125.

Fig. 3. L.S. pericarp with intracellular mycelium. Note pronounced hole in wall through which hypha passes. × 1125.

Fig. 4. Surface preparation of pericarp with, *on left*, swelling beneath epidermis through which hypha passes, and *on right*, a penetrated hypha with sheathing. Note stained ring near point of entry. × 900.

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REVIEWS

MICROCARDS FOR MYCOLOGISTS

It is common knowledge, although not often explicitly stated, that the size of the literature is becoming the modern crisis of science. The vast output of scientific publication tends to impede the exchange of the results of research and of ideas on which the advance of science depends, and it is becomingly increasingly difficult for many workers to ascertain what has been accomplished in their particular fields, let alone the results in other specialities which could have an application to their own. Although scientists are by training perhaps more rational and more willing to accept and assimilate the novel than are other men, they show little evidence of these attributes outside the laboratory. The methods by which the results of scientific research are published, for example, have grown haphazardly from those appropriate for the small groups of amateur and professional natural philosophers who were often in close touch with one another and able to keep abreast of the state of knowledge in even a major branch of science. Virtually no attempts have been made to rationalize the publication of scientific papers and little has been done to employ new techniques to the compilation and analysis of the data already available. This is not the place to discuss these major issues. The above somewhat platitudinous statements are only intended as a background for a brief review of the application of one recent technique to the dissemination of data in one branch of mycology.

It is said that the daily increase in the literature of chemistry is 5000 printed pages. The daily output in the plant sciences is perhaps a tenth of this figure (Wellensiek (*Proc. VI internat. bot. Congr.* **1**, 83) estimated the botanical output in 1935 as 300 printed pages a day) and in the relatively small field of mycology the annual total may not exceed 5000 books and papers. The life of most effectively publicized papers on experimental mycology is, like similar papers in other fields, comparatively short. Many of the best papers are soon superseded by the work which they stimulate when the papers themselves become of interest only to historians. The results of taxonomic work, on the other hand, though less spectacular, tend to have a much longer life and it is to taxonomic publications of the past on which attention will be mainly focused here.

Recent mycological taxonomic publications (issued at a rate of possibly 1000 books and papers a year) are compiled by various abstracting organizations and most contributions in which any one taxonomist is currently interested thus come to his attention within a year or two of publication. The taxonomic literature dealing with fungi, however, extends back for 150 years. There have been several attempts to compile the literature of the past; the two most outstanding being Saccardo's *Sylloge Fungorum* and Lindau and Sydow's *Thesaurus literaturae mycologicae*, but such invaluable compilations do not obviate the necessity to consult and study the original sources. Many of these sources are scarce and expensive and the resulting difficulty of access is certainly one factor leading to failures by modern taxonomists to propose acceptable taxa and to use internationally acceptable names. The position would be alleviated if, as a beginning, a selection of the more important mycological taxonomic classics could be made generally available. A redistribution of the original is impracticable and this could never provide a complete solution as there are insufficient copies of many works to meet the need. Some form of reproduction must be resorted to and if the objective is to be attained of giving the maximum number of mycologists day to day access to the reproductions one essential of any method is that it should be inexpensive. The method of choice would appear to be 'microcards'.

'Microcards' were first suggested and their possibilities indicated by Fremont Rider, librarian of the Wesleyan University, Middletown, Conn., in his book *The Scholar and the future of the research library*, 1944. Subsequently, in the United States methods for the large-scale manufacture of microcards were developed (at a cost during the first 5 years of more than a quarter of a million dollars) and the publishing organization set up is known as The Microcard Foundation, 'a non-profit making educational institution'. More recently microcards have also been made in other countries.

A microcard is a 3 × 5 in. (7·5 × 12·5 cm.) index card on one side of which there is a catalogue entry surmounting 30–150 pages in microprint of the publication catalogued, each page of the original being commonly reduced to approximately 12 × 7 mm. The cards are read by means of an apparatus, based on the principle of an epidiascope, by which an image is projected onto a screen; the size of the image being usually about the same size as the original. The cards can, however, in the absence of a special reader be conveniently consulted in the laboratory by means of a binocular microscope or even of a × 10 hand-lens.

Microcards are relatively inexpensive. The selling price depends on the size of the edition but it is usually an eighth or less of that of a facsimile produced by the photo offset process (e.g. $8.50 instead of $60.00 for Fries's *Systema mycologicum*). They have the additional advantage that they take up little space (the volume of the microcard edition of the *Systema* is less than $\frac{1}{25}$th of that of the original books) and may be stored in standard filing cabinets where they are self-indexing. Further, there are no binding costs.

The almost invariable first reaction of mycologists to the idea of microcards is the retort that the printed books are to be preferred. This is quite to misunderstand the function of microcards. The original books (or facsimiles) are, other things being equal, naturally to be preferred. The type of question that a mycologist must ask himself is, does the pleasure and convenience of handling books justify spending an additional £20 for access to the information in the *Systema*? For workers in important mycological herbaria and large institutions the answer would often be in the affirmative but for individual systematists and most departmental libraries it is microcards or nothing.

Microcards thus supplement books. Likewise they supplement rather than replace microfilm which is still the cheapest method for obtaining a single copy. Microcards, as Miles Price has pointed out, are essentially not a new method of copying but a new method of publishing, a method that could find many applications in the dissemination of bulky theses and other bodies of data of limited appeal and in such novel developments as the issue by the Commonwealth Mycological Institute of diagnoses of new species of fungi on microcards as a supplement to the *Index of Fungi*.

Microcards have now been given a sufficient trial (as a glance at the catalogue of the Microcard Foundation will show) to justify the belief that they will become increasingly popular. A few very useful mycological source books and a few journals of interest to mycologists are already available on microcards but many more items from the older (and non-copyright) mycological taxonomic works merit reproduction in this form. There is no reason why every institute interested in fungi and many individual specialists should not eventually possess collections of taxonomic works such as those at present found only in the larger herbaria and in the libraries of older or more wealthy foundations. Mycologists can help towards this very desirable situation by showing their appreciation of the start that has been made and by co-operating on a national and international scale in planning further developments.

Among microcard editions of interest to mycologists are: Fries, *Systema mycologicum* (and the *Elenchus*), 4 vols., 1821–32, $8.40; Persoon, *Synopsis methodica fungorum*, 2 vols., 1805, $2.50; Buller, *Researches in Fungi*, vols. 1–6, 1908–34 (in preparation); *Hedwigia*, 1852–1942 (vols. 1–81 and index vols. 1–50), $139.60; *Archiv. Protistenkunde*, 1902–43 (vols. 1–96 and indices 1–50), $154.40. (Microcard Foundation, Middletown, Conn., U.S.A.); *Index of Fungi*, **2**, *Microcards of diagnoses*, Cards 1–25, 25*s*. (Commonwealth Mycological Institute, Kew, Surrey).

G. C. AINSWORTH

Les Discomycètes de Madagascar. By MARCELLE LE GAL. Paris: Muséum National d'Histoire Naturelle.) 465 pp., 172 figures. May 1953. Price 6500 fr. in France, 8000 fr. abroad.

In this volume we find precise descriptions and excellent figures of eighty Discomycetes collected in Madagascar; all are based on dried or preserved material and field observations are lacking. The species are disposed as to 23 Operculates, 19 Sarcoscyphaceae and 28 Inoperculates and, of the whole, only 10 are European. The identification of the species involved, their comparison with numerous collections from divers national herbaria and the critical comments on these extend the scope of the work far beyond the confines of Madagascar and greatly enhance its value. The results of these studies are brilliantly used in a continuance of the author's search for improved generic delimitation, and it is pleasing to find the international Code of Nomenclature held in respect throughout. Opinions may well differ upon many of the taxonomic conclusions reached, but Dr Le Gal's views are well reasoned and must command respect if not always agreement. Mention of a few points will indicate the wide scope of the subject-matter. *Aleuria* is submerged as an e-gluttulisporous section within *Galactinia*. *Peziza* is discarded; there will surely be some heartburning about this, and one senses a little wistfulness in the author when she concludes her argument for rejection with the question: 'Son abandon peut-il être, après tout, si regrettable?' *Scutellinia* is revived to supersede *Ciliaria et al.* The Inoperculates present a less coherent picture but are equally well treated individually; *Calycella* is regarded as of no higher status than a section within *Helotium*. The Sarcoscyphaceae—so richly represented in Madagascar—are fully treated, and keys are provided for thirteen species of *Phillipsia* and for seven of *Plectania*. The suboperculate ascus was also detected in a species of *Trichophaea* on the one hand and, on the other, in a species of *Rutstroemia*. Clearly, the original Boudier concept is breaking down; indeed, the author is tempted to suggest that the mode of ascus dehiscence may not have the importance hitherto assigned to it and that we should, perhaps, look elsewhere—probably to the spore—for the foundations of Discomycete taxonomy.

The book concludes with a chapter on the world distribution of the Madagascar species, followed by a short discussion of phylogeny within the Sarcoscyphaceae and their near relatives. There is an extensive bibliography and the book is well indexed.

This is a stimulating volume; every page reveals the meticulous care with which it has been written. It sets a standard for elegant and lucid presentation of critical taxonomic work and one can only regret that its high price may well deprive many of the benefits to be gained from its study.

W. D. GRADDON

Deterioration of Materials: Causes and Preventive Techniques. Ed. by G. A. Greathouse and C. J. Wessell. (New York: Reinhold Publ. Co. 1954.) Pp. xvii+835, illus. 96*s*.

The Tropical Deterioration Center, Washington, was founded in 1943 to deal with the problems of the maintenance of military stores in the Far Eastern theatre of war. After the war it became the Prevention of Deterioration Center, under the National Research Council of the National Academy of Sciences, and its work was extended to cover all such problems, whether of jungle origin or not. This book, compiled by twenty-four contributors, embodies the accumulated experience of over a decade of intensive research. Although dealing mainly with American investigations, it nevertheless takes into account the work of similar bodies in various countries of the Commonwealth.

The volume is in four sections. The first section, of 233 pages, is concerned with Important Factors in Deterioration, and includes chapters on climatic, physical and chemical, and biological agents respectively. In the latter chapter the characteristics of the various groups of organisms—fungi, bacteria, insects, crustacea, and rodents—are briefly described in terms suitable for the non-specialist, the fungi occupying 14 pages.

The next two sections, comprising the major portion of the book, deal with methods of protection of various types of materials and some kinds of assembled equipment. Since all such materials, except metals, are liable to attack by fungi, considerable portions of the various chapters are devoted to the results and prevention of fungal attack.

The fourth section of the book concerns Some Special Aspects of Prevention, the chapters being on Dehumidification, Packaging, and Toxicological Evaluation of Preservatives.

In general, the mycological aspects of the subject are competently handled, and the many photographic illustrations are to the point. The book is well indexed and attractively produced, and should serve as a useful source of reference for all who are interested in this branch of applied mycology.

G. SMITH

Les Champignons. Tome II. By F. MOREAU. (*Encyclopédie Mycologique*, XXIII. Paris: Paul Lechevalier. 1953.) Pp. 941–2120, 835 text-figures. Price of Tomes I and II, French francs 26,000 (not sold separately).

While the first volume of Prof. Moreau's *Les Champignons* deals with fungi from a biological point of view, this second volume, entitled 'Systématique', is concerned with structure and classification. It is introduced by a chapter on rules of nomenclature and methods used by the mycological systematist. A brief discussion of the structure and relationships of 'les organismes fungoïdes', Actinomycetes, chlorophyll-lacking flagellates and Myxomycetes, precedes consideration of the fungi proper and the text ends with a chapter on phylogeny. Then follows a list of corrections and additions, and, in turn, an index to authors and to genera. Finally, the book ends with the table of contents of both volumes I and II.

No two authors of books of this sort adopt identical systems of classification and Prof. Moreau's latest contribution will be of particular interest in this respect for he departs somewhat from the familiar primary division of fungi into Phycomycetes, etc. Instead, and reflecting his views of the flagellate ancestry of fungi, he bases his primary division of the group into Mastigomycètes and Amastigomycètes on the presence or absence of flagella. This results in the disappearance of the familiar Phycomycetes as such and the redistribution of its members amongst the above two groups. There may not be general agreement with Prof. Moreau's scheme, from which I have quoted perhaps the most radical departure from the more familiar system of classification, on which most of us were brought up. The value of a book such as this, however, lies not only in the accounts of fungi which it contains but also in the extent to which those who read it are provoked to think more about fungus relationships, which this book will undoubtedly do. Prof. Moreau is also to be congratulated on a very comprehensive survey of the fungi themselves, profusely illustrated by text-figures and with an extensive bibliography.

The price of volume I was referred to (*Trans. Brit. mycol. Soc.* **36**, 269, 1953) as monumental. The price of volumes I and II, quoted together as 26,000 francs, verges on the astronomical. *Les champignons* is altogether too expensive.

C. J. HICKMAN

Potato Diseases. By ROBERT MCKAY. (Dublin: Irish Potato Marketing Company Ltd. At the Sign of the Three Candles. 1955.) x + 126 pp., 4 colour and 103 half-tone plates. Price: 21*s*.

This is a well-illustrated book, pleasing to handle and to look upon, giving a clear and straightforward account of each of the principal diseases of the potato. It is intended primarily for those engaged in the potato trade, as growers, seedsmen or exporters, but it contains enough of mycology and virology to give agricultural students a good introduction to the well-established parts of the pathology. Much recent, controversial or research matter is deliberately excluded, and the book is squarely based in the main on the fine work done in Ireland, by Pethybridge, Murphy, Davidson, and latterly Dr McKay himself and his colleagues. Some of the information, especially on varietal reactions to viruses, will be of special interest to virus workers, as it does not appear to be available elsewhere. Perhaps one could have wished for more on mineral deficiency troubles than about half a page on 'Rust' and a page on 'Yellowing', but on the whole the treatment of the many diseases and disorders of the potato is well balanced according to their economic importance and, like Davidson's *Potato Growing for Seed Purposes*, this book will surely find a welcome wherever potatoes are grown.

E. C. LARGE

Mushroom Research Association Limited: Final Report 1954. (Distributors: Mushroom Growers Association, 43 Bedford Square, London, W.C. 1. 1955.) 36 pp. Price: 5*s*.

Mycologists will not allow the closing of the M.R.A. laboratories at Yaxley, and the transfer of the work to the new Glasshouse Crops Research Institute near Littlehampton, to pass unnoticed and without expressing appreciation of the progress made by R. L. Edwards and his staff under the Chairmanship of Fred C. Atkins. This final report describes further experimental work on commercial mushroom production, and has an account by D. G. Gandy of 'bacterial pit' and of the various 'yellow moulds'. It ends with a useful list of M.R.A. publications.

Illustrated Genera of Imperfect Fungi. By H. L. Barnett. (Minneapolis: Burgess Publishing Co. 1955.) Price: U.S. $4.00.

Drawings showing microscopic detail of fructification of over 300 genera of Fungi Imperfecti form a useful tool to help the inexperienced to identify genera. There is a key to the genera, and opposite each drawing is a brief description of the genus. Many of the drawings are originals by Prof. Barnett (182 genera), and the remainder are copied from well-known sources.

The Genus Inocybe (*Naturalist, Lond.*, 1954, pp. 117–140); Mycena, (*Naturalist, Lond.*, 1955, pp. 41–63). By A. A. Pearson. (Reprints obtainable from the editor, *The Naturalist*, The University, Leeds 2. 2*s*. 6*d*. each.)

These two useful little monographs, which are on similar lines to the late Mr Pearson's earlier keys, were prepared for publication by Dr R. W. G. Dennis.

CULTURE COLLECTION OF THE DEPARTMENT OF MYCOLOGY, LISBON

The Department of Mycology, Faculty of Science, Lisbon, maintains a culture collection of fungi. It comprises about 1000 strains, mostly Polyporaceae and Yeasts, which are being used for research work, as well as some belonging to other groups, which are being maintained for identification and teaching purposes.

Two catalogues have been recently published, the first listing the Hymenomycetes and the second the Phycomycetes, Ascomycetes and Deuteromycetes; the section comprising the Yeasts is not yet published. The catalogues can be obtained free of charge.

When available, cultures will be sent on request. They are sent free of charge to Institutes or workers doing likewise. Otherwise only exchange can be considered. All correspondence should be addressed to the head of the Department, Prof. J. Pinto-Lopes, Faculdade de Ciencias, Lisboa, Portugal.

Trans. Brit. mycol. Soc. **38** (4) 481–503 (1955).

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Corrected to 30 July 1955

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Atkins, F. C., Yaxley, Peterborough, Northants. (1945.) Mushroom diseases.

Austwick, P. K. C., Mycology Laboratory, Ministry of Agriculture, Fisheries and Food, Veterinary Laboratory, New Haw, Weybridge, Surrey. (1946.) Basidiomycetes, esp. Polyporaceae and resupinates; Myxomycetes; medical and veterinary mycology; ecology.

Ayerst, G., B.Sc., Pest Infestation Laboratory, London Road, Slough, Bucks. (1954.) Mycology of grain storage; field mycology.

Aytoun, R. S. C., 18 Sefton Paddock, Stoke Poges, Bucks. (1950.) Antibiotics; genetics; soil fungi; plant pathogenic fungi.

Badcock, E. C., Forest Products Research Laboratory, Princes Risborough, Bucks. (1944.)

Baker, J. J., B.Sc., 7 Cardington Road, Bedford. (1953.)

Baker, Professor K. F., University of California, 405 Hilgard Avenue, Los Angeles 24, California, U.S.A. (1946.) Diseases of ornamental plants; seed-borne diseases.

Balfour-Browne, Mrs F. L., M.Sc., Department of Botany, British Museum (Natural History), Cromwell Road, South Kensington, London, S.W. 7. (1930.)

Banbury, G. H., B.Sc., Department of Botany, University College, Ibadan, Nigeria, British West Africa. (1949.) Physiology; soil fungi and mycorrhiza, esp. tropical.

Bannan, Miss L., B.Sc., A.R.C.S., 8 Belgrave Road, Chorlton-cum-Hardy, Manchester. (1945.)

Barnes, Miss E. M., B.Sc., Ph.D., Low Temperature Research Station, Downing Street, Cambridge. (1943.) Fungi concerned with food spoilage; edible fungi; large-scale culture of fungi.

Barrington, Dr F. J. F., 14A Upper Wimpole Street, London, W. 1. (1901.)

Bates, G. R., Ph.D., c/o Division of Agriculture and Lands, Branch of Botany and Plant Pathology, P.O. Box 100, Causeway, Salisbury, Southern Rhodesia. (1930.) Tropical and subtropical plant diseases, esp. of citrus and tobacco; Microthyriales and Fungi Imperfecti.

Batista, Professor A. C., Departmento de Micologia, Universidade do Recife, Rua do Espinheiro, 386, Recife, Pernambuco, Brazil. (1950.) General mycology and taxonomy.

Batko, Dr S., Forestry Commission, Alice Holt Lodge, Wrecclesham, nr Farnham, Surrey. (1944.)

Batts, C. C. V., B.Sc., Ph.D., National Institute of Agricultural Botany, Huntingdon Road, Cambridge. (1946.) Diseases of crop plants, esp. rusts and smuts.

Bawden, F. C., M.A., F.R.S., Rothamsted Experimental Station, Harpenden, Herts. (1941.)

Beaumont, A., M.A., Block 2, Government Buildings, Lawnswood, Leeds 6. (1924.) Plant pathology and epidemiology.

Beedham, Mrs M., B.Sc., Ph.D., Ystwyth, Godstone Road, Bletchingley, Surrey. (1948.)

Beevor, M. B., Hazel Croft, Cheveley, Newmarket, Suffolk. (1952.)

Bennett, A. J., 84 Henhurst Hill, Burton-on-Trent, Staffs. (1948.) Yeasts; industrial mycology.

Bennett, Miss M., B.Sc., East Malling Research Station, nr Maidstone, Kent. (1945.)

Bewley, W. F., C.B.E., D.Sc., Experimental and Research Station, Cheshunt, Herts. (1922.)

Biggs, Miss R., B.Sc., Ph.D., M.B., B.S., The Radcliffe Infirmary, Oxford. (1945.)

Bilton, P. A., B.Sc., M.Sc., Cambridgeshire High School for Boys, Hills Road, Cambridge. (1950.)

Biraghi, Professor A., Professor of Plant Pathology, Istituto di Patologia Forestale e Agraria, Facoltà Agraria e Forestale, Università degli Studi, Piazzale delle Cascine, Firenze, Italy. (1953.)

Birkinshaw, J. H., D.Sc., Darien, 18 West End Road, Pinner, Middx. (1946.) Metabolic products of fungi, esp. wood-rotting and micro-fungi; field-study of higher fungi.

Bisby, G. R., Ph.D., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1921.)

Blackman, Professor V. H., M.A., Sc.D., F.R.S., F.L.S., 17 Berkeley Place, Wimbledon, London, S.W. 19. (1900.)

Blackwell, Miss E. M., M.Sc., F.L.S., Woodsome Lees, Kirkburton, nr Huddersfield, Yorks. (1917.) *Phytophthora*; aquatic phycomycetes; records of Yorkshire fungi.

Blumer, Dr S., Schoënenbergstrasse 85, Waedenswil, Switzerland. (1936.)

Boardman, Mrs S., 109 Monkhams Avenue, Woodford Green, Essex. (1950.) Larger British fungi.

Bond, T. E. T., D.Sc., Ph.D., F.L.S., Horticultural Science Laboratories (University of Bristol), Bracken Hill, Leigh Woods, Bristol 8. (1945.) Taphrinales; evolutionary aspects of parasitism in fungi; diseases of ornamentals.

Booij, Dr H. L., 34 Stanhope Gardens, Highgate, London, N.6. (1954.)

Booth, C., B.Sc., M.Sc., 24 Raleigh Road, Feltham, Middx. (1953.)

Bottomley, T. L. C., 23 Ryegate Crescent, Sheffield 10. (1950.) Aquatic Hyphomycetes and phycomycetes; discomycetes.

Boyd, A. E. W., B.Sc., Ph.D., East of Scotland College of Agriculture, 13 George Square, Edinburgh. (1947.) Plant pathology; diseases of potatoes; agarics.

Bradbury, J. F., B.Sc., Imperial College of Science and Technology, South Kensington, London, S.W. 7. (1955.) General mycology; physiology; industrial mycology.

Bradley-Jones, J., N.A.A.S., Plant Pathology Department, University College, Cathays Park, Cardiff. (1948.)

Brady, Miss B. L., B.Sc., Swanmead, Datchet, Bucks. (1948.)

Brenchley, G. H., M.A., N.A.A.S., Anstey Hall, Trumpington Road, Cambridge. (1925.)

Brett, Miss M., M.Sc., Ph.D., F.L.S., Greenhills, St Andrews Road, Bridport, Dorset. (1921.) Smuts, esp. *Thecaphora*, *Sorosporium*; insects and fungi; Fungi Imperfecti, esp. *Cladosporium*.

Brian, P. W., Sc.D., Imperial Chemical Industries, Ltd., Akers Research Laboratories, Welwyn, Herts. (1944.) Antibiotics; fungal toxins; soil fungi; microbial antagonisms.

Brierley, J. K., 25 Lilac Avenue, Kingsway, Derby. (1951.)

Briggs, P. A., 5 Redway Drive, Twickenham, Middx. (1953.)

Brind, Mrs J. E., Rothamsted Experimental Station, Harpenden, Herts. (1948.)

Broadfoot, Miss J., B.Sc., c/o Lloyds Bank, Staines, Middlesex. (1945.)

Brodie, H. J., Ph.D., Department of Botany, Indiana University, Bloomington, Indiana, U.S.A. (1952.) Heterothallism in higher basidiomycetes; spore discharge and dispersal; Nidulariaceae; physiology.

Brooke, J., Rowmore, Leigh Hill Road, Cobham, Surrey. (1947.) Agarics; colour photography of fungi.

Brooke, M., B.Sc., M.I.Biol., 7 Highgrove Avenue, Chilwell, Notts. (1952.) Plant pathology, esp. chemical control; laboratory testing of fungicides.

Brooks, J. S., The Research Department, Carreras Ltd., 221 Stanhope Street, London, N.W.1. (1951.)

Brown, Miss A. H. S., Ph.D., 28 Abinger Road, Bedford Park, London, W.4. (1950.) Hyphomycetes, esp. *Paecilomyces*, *Penicillium*, etc.

Brown, Miss J. C., B.Sc., Highbarn Eaves, Effingham, nr Leatherhead, Surrey. (1952.) Soil fungi, esp. of sand dunes.

Brown, Professor W., M.A., D.Sc., F.R.S., The Bush, Haddenham, Aylesbury, Bucks. (1922.)

Buchwald, Professor N. F., Royal Agricultural and Veterinary College, Rolighedsvej 23, Copenhagen V, Denmark. (1946.)

Buckley, W. D., St Anthony, Leigh Park, Datchet, Bucks. (1916.) Discomycetes.

Bull, Miss P., 14 Gresham Road, Hounslow, Middx. (1952.)

Bulloch, M. G., The Cottage, New Road, Littlehampton, Sussex. (1949.)

Bundy, J. W., B.Sc., Food Research Department, Colworth House, Sharnbrook, Bedford. (1951.)

Burges, Professor N. A., Department cf Botany, The University, Liverpool. (1935.)

Burnett, J. H., M.A., D.Phil., Hartley Botanical Laboratories, The University, Liverpool 3. (1948.) Physiological genetics of fungal reproduction; genetics of natural populations of fungi.

Butterworth, D., Ministry of Supply, Tropical Testing Establishment, Port Harcourt, Nigeria. (1950.)

Buxton, E. W., Mycology Department, Rothamsted Experimental Station, Harpenden, Herts. (1952.) Plant pathology, esp. genetic variability in the pathogen.

Byford, W. J., Department of Agriculture for Scotland, Plant Pathology Laboratory, East Craigs, Corstorphine, Edinburgh 12. (1951.) Plant pathology, esp. cereal diseases and testing for clubroot resistance.

Byrde, R. J. W., B.Sc., Ph.D., Homeleigh, Downside, West Town, nr Bristol. (1952.) Epidemiology of *Sclerotinia fructigena*; physiology in relation to fungicides.

Bywater, Miss J., B.Sc., Department of Botany, The University, Edgbaston, Birmingham 15. (1953.)

Caldwell, Mrs B. J., B.Sc., Department of Cryptogamic Botany, The University, Manchester 13. (1943.)

Caldwell, Professor J., D.Sc., Ph.D., Department of Botany, University College, Exeter. (1932.)

Caldwell, R., 31 Orient Road, Salford 6, Lancs. (1950.)

Callen, E. O., B.Sc., Ph.D., F.L.S., Department of Plant Pathology, Macdonald College Post Office, McGill University, Quebec, Canada. (1941.) Mucorales; soil fungi; endophytic fungi; aerobiology.

Campbell, A. H., B.Sc., Ph.D., Glaxo Laboratories Ltd., Fermentation Research Division, Sefton Park, Stoke Poges, Bucks. (1934.)

Campbell, W., B.Sc. (Agr.), N.A.A.S., Staplake Mount, Starcross, Exeter, Devon. (1951.)

Cannons, C. E., 35 Langley Oaks Avenue, Sanderstead, Surrey. (1951.)

Canter-Lund, Dr Hilda, Freshwater Biological Association, The Ferry House, Far Sawrey, Ambleside, Westmorland. (1944.) Aquatic Phycomycetes, esp. those living on algae.

Carr, A. J. H., B.Sc., Welsh Plant Breeding Station, Aberystwyth. (1949.) Plant pathology, esp. grasses and herbage legumes; breeding for disease resistance; genetics and cytology of fungi.

Cartwright, K. St G., M.A., F.L.S., The Old Vicarage, Towersey, Thame, Oxon. (1913.) Forest and timber mycology.

Catsimbas, C., Plant Pathology Laboratory, Agricultural College of Athens, Botanical Gardens, Athens, Greece. (1947.)

Caulton, D. E., 45 Ash Grove, Headingley, Leeds 6. (1949.) Microfungal ecology; taxonomy; social aspects of mycology in schools.

Cavett, J. J., B.Sc., c/o A.R.C. Potato Storage Investigation, Nottingham University School of Agriculture, Sutton Bonnington, Loughborough, Leics. (1951.) Soil microbiology and the rhizosphere.

Chapman, F. P., P.O. Box 1308, Cape Town, South Africa. (1952.) Higher fungi.

Charlton, Mrs K. M., Four Oaks, Billingbear Lane, Binfield, Berks. (1945.)

Cheal, W. F., Quarry Bank, London Road, West Malling, Kent. (1927.)

Chesters, Professor C. G. C., B.Sc., M.Sc., Ph.D., Department of Botany, The University, Nottingham. (1930.)

Chowdhury, S., Government Mycologist, Jorhat, Assam, India. (1949.)

Christensen, Dr C. M., University Farm, St Paul 8, Minn., U.S.A. (1945.)

Ciferri, Professor R., Director, Laboratorio Crittogamico, Casella Postale 165, Pavia, Italy. (1926.)

Clayton, Yvonne M., Department of Medical Mycology, Institute of Dermatology, St John's Hospital, Lisle Street, Leicester Square, London, W.C. 2. (1954.) Medical mycology.

Cleary, J. P., N.A.A.S., Block 2, Government Buildings, Lawnswood, Leeds 6. (1948.)

Cleasby, W. B., Lower Honeydon Farm, nr Bedford. (1949.)

Cleland, J. B., M.D., Professor of Pathology, University of Adelaide, South Australia. (1918.)

Codner, R. C., B.Sc., M.I.Biol., Rippleside, Walton Down, nr Clevedon, Somerset. (1955.) Antibiotics; actinomycetes; hyphomycetes, esp. *Cephalosporium* and allied genera.

Cole, J. S., B.Sc., Ph.D., D.I.C., c/o Tobacco Research Board of Southern Rhodesia, P.O. Box 1909, Salisbury, S. Rhodesia. (1953.) Plant pathology.

Colhoun, J., B.Sc., M.Agr., Ph.D., D.I.C., Plant Disease Division, Ministry of Agriculture, Queen's University, Belfast, N. Ireland. (1943.) Plant pathology, esp. diseases of fruit and flax; club-root; biological evaluation of fungicides.

Collett, Mrs F. W. M., Townsend Farm, Littleton Drew, Chippenham, Wilts. (1948.)

Collinge, A. C., Norbreck, 37 Warley Road, Halifax. (1951.)

Colombo, Mrs G. M., 32 Carlyle Road, Staines, Middx. (1950.) Medical mycology.

Colyer, J., 3, Wychurst Gardens, Bexhill-on-Sea, Sussex. (1954.) Agricultural mycology.

Cone, Mrs G. B., Ph.D., D.I.C., 93 Kawai Street, Nelson, New Zealand. (1951.) Agarics of N.Z.; bacterial symbiosis.

Cooke, Mrs A., B.Sc., F.L.S., 20 Grand Avenue, Hassocks, Sussex. (1938.)

Cooper, Mrs V. A., Wyndcliffe, Granville Park, Aughton, Ormskirk, Lancs. (1921.)

Corke, A. T. K., Long Ashton Research Station, Long Ashton, nr Bristol. (1955.)

Corner, E. J. H., F.R.S., Botany School, Downing Street, Cambridge. (1924.) Taxonomy; morphology; Basidiomycetes; Ascomycetes.

Cornford, C. E., 149 Monk's Road, Lincoln. (1953.)

Cotton, A. D., O.B.E., V.M.H., F.L.S., Honey Cottage, Farnham Common, Bucks. (1902.)

Cottrell, A. R., B.Sc., I.C.I. Ltd., Research Department, Dyestuffs Division, Hexagon House, Blackley, Manchester 9. (1948.)

Coulthard, C. E., M.P.S., 51 Henry Road, West Bridgford, Nottingham. (1954.) Fermentation; antibiotic production; field work.

Cousins, P. J., 15 Baldwyns Road, Bexley, Kent. (1951.) Plant pathology; disease surveys; predacious fungi.

Cox, Miss B. J., B.Sc., Elm Lodge, Englefield Green, Surrey. (1953.)

Cox, Miss V. J., B.Sc., Department of Botany, Birkbeck College, Malet Street, London, W.C. 1. (1953.)

Craig, J. K., Craigs, Ltd., The Marsh, Widnes, Lancs. (1952.) Fungi associated with wood and trees.

Critopoulos, Dr P. D., D.Sc., F.L.S., University of Athens, 104 Solonos Street, Athens, Greece. (1949.) Teaching of general plant pathology; cereal rusts; *Phytophthora* diseases; virus diseases of grape.

Crosse, J. E., B.Sc., Research Station, East Malling, Kent. (1948.)

Crosse, R., The Brambles, 12 Sefton Paddock, Stoke Poges, Bucks. (1951.)

Crowdy, S. H., B.Sc., Ph.D., I.C.I. Ltd., Akers Research Laboratories, The Frythe, Welwyn, Herts. (1946.) Plant pathology; systemic and protectant fungicides.

Croxall, H. E., B.Sc., Ph.D., N.A.A.S., Elswick Hall, Elswick Park, Newcastle-on-Tyne 4. (1937.) Plant pathology, esp. diseases of vegetables and fruit; disease assessment; fungicides; Pyrenomycetes.

Cunnell, G. J., B.Sc., Department of Botany, Birkbeck College, Malet Street, London, W.C. 1. (1954.)

Curtis, Miss K. M., M.A., D.Sc., F.L.S., Cawthron Institute, Nelson, New Zealand. (1917.) Phytopathology (fruit, tobacco, hops); soil sterilization; cytology.

Cury, A., Mycology Laboratory, Instituto Oswaldo Cruz, Caixa Postal 926, Rio de Janeiro, Brazil. (1950.)

Dade, H. A., A.R.C.S., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1927.) Hyphomycetes, esp. *Aspergillus*; culture collections; techniques; colour; microscopy and photomicrography.

Damiano, C., 81 Exeter House, Putney Heath, London, S.W. 15. (1946.)

Darlington, R. G., Southcourt Road, Worthing, Sussex. (1949.)

Davies, D. L. G., Ph.D., N.A.A.S., Crosswood, Aberystwyth, Cards. (1938.)

Davies, D. W., B.Sc., Afallon, Llanbadarn Road, Aberystwyth, Cards. (1923.)

Davies, H. M., B.Sc., Ph.D., 43 Garrick Close, Walton-on-Thames, Surrey. (1944.) Larger fungi; mycophagy.

Davis, Mrs L. H., M.A., Plant Pathology Department, University of California, Los Angeles 24, California, U.S.A. (1949.) Pathogenic fungi of floricultural crops, esp. Fungi Imperfecti.

Day, P. R., B.Sc., Ph.D., Plant Pathology Department, College of Agriculture, University of Wisconsin, Madison 6, Wis., U.S.A. (1955.) Genetics of micro-organisms; plant pathology.

Day, W. R., B.A., B.Sc., Imperial Forestry Institute, Oxford. (1928.)

Deighton, F. C., O.B.E., M.A., Linden Lea, Leigh Place, Cobham, Surrey. (1925.) Tropical fungi, esp. Meliolaceae, Asterinaceae and Hyphomycetes.

Dickinson, S., Ph.D., School of Agriculture, Cambridge. (1921.)

Digilio, A. P. L., D.Sc., Instituto Miguel Lillo, Calle Miguel Lillo 205, Tucumán, Argentina. (1952.) Taxonomy of fungi of temperate South America, esp. Basidiomycetes.

Dillingham, Mrs M. E. K., B.Sc., N.D.H., 21 Cardigan Road, Richmond, Surrey. (1949.) Plant pathology, esp. seed-borne diseases, soil-borne diseases, root disease fungi.

Dixon, P. A., B.Sc., Botany Department, Birkbeck College, London, W.C. 1. (1955.)

Dobbs, C. G., B.Sc., Ph.D., Department of Botany, University College of North Wales, Bangor. (1933.) Mucorales; spore dispersal; soil mycology; ecology, esp. woodland, Arctic and mountain; forest pathology; mycorrhiza; brewing.

Dodge, C. W., Missouri Botanical Garden, 2315 Tower Grove Avenue, St Louis 10, Miss., U.S.A. (1926.)

Dorey, M. J., New Timbers, Laleham-on-Thames, Staines, Middx. (1950.)

Dovaston, H. F., B.Sc., Ph.D., West of Scotland Agricultural College, Auchincruive, By Ayr. (1946.) Fungal diseases of tomato.

Downie, Dr Dorothy G., Botany Department, The University, Aberdeen. (1954.)

Dring, D. M., B.Sc., 559 Lincoln Road, Peterborough, Northants. (1953.) Plant pathology; *Mycosphaerella*; genetics.

Duddington, C. L., M.A., Ph.D., F.L.S., Biology Department, The Polytechnic, Regent Street, London, W. 1. (1946.) Predacious fungi; biological control of nematodes; teaching.

Dulaney, E. L. B. S., M.A., Ph.D., Research and Development Division, Merck & Co. Inc., Rahway, New Jersey, U.S.A. (1950.) Physiology; genetics; industrial microbiology.

Duncan, Miss C. W. H., Glaxo Laboratories, Ltd., Ulverston, Lancs. (1949.)

Duncan, J. T., F.R.C.S., L.R.C.P., 31 Nightingale Road, Rickmansworth, Herts. (1930.) Medical mycology.

Dunston, Capt. A. E. A., Poolahash, Ballycorus Road, Kilternan, Co. Dublin, Eire. (1937.)

Dunston, T. F. G. W., B.A., Burlton, Donhead St Mary, Shaftesbury, Dorset. (1947.) Larger Basidiomycetes.

Durbin, R. D., B.S., Plant Pathology Department, University of California, Los Angeles 24, California, U.S.A. (1953.) Diseases of ornamentals; soil organisms, esp. *Rhizoctonia solani*.

Eades, B. W., 414 Shaftmoor Lane, Hall Green, Birmingham 28. (1952.) Fungi in buildings.

Ebben, Miss M. H., M.A., Glasshouse Crops Research Institute, Worthing Road, Rustington, Littlehampton, Sussex. (1951.) Root disease of the tomato and the relation of rhizosphere organisms to its increasing severity under continuous cropping.

Edney, K. L., B.Sc., A.R.C.S., Ditton Laboratory, East Malling, nr Maidstone, Kent. (1955.)

Elek, S. D., M.D., Ph.D., D.P.H., Department of Bacteriology, St George's Hospital Medical School, London, S.W. 1. (1954.)

Elliott, A. L., 29 High Street, Pershore, Worcs. (1949.)

Elliott, Mrs J. S. B., D.Sc., Dulverton, Manor Way, Aldwick Bay, nr Bognor Regis, Sussex. (1911.)

Ellis, E. A., F.L.S., Castle Museum, Norwich. (1937.) Micro-fungi; all fungi of marshes and dunes.

Ellis, M. B., B.Sc., Ph.D., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1945.) Hyphomycetes; marsh and fen fungi.

Emerson, R., Department of Botany, University of California, Berkeley, California, U.S.A. (1938.)

English, Miss M. P., M.Sc., Pathology Department, Bristol General Hospital, Bristol 1. (1943.) Medical mycology, esp. the dermatomycoses; agarics; osmophilic yeasts and other industrial contaminants; diseases of fruit.

De Escosteguy, Miss Maria C. C. Department of Botany, The University, Edgbaston, Birmingham 15. (1954.)

Evans, B. D., D.Sc., Hackmead, 9 Western Road, Suttton, Surrey. (1951.) Industrial fermentations, esp. antibiotics; variation in pure lines or strains.

Evans, E., M.Sc., Chesterford Park Research Station, nr Saffron Walden, Essex. (1952.) Soil ecology; soil pathology.

Fahim, Moustafa M., B.Sc., Department of Botany, The University, Glasgow. (1954.) Plant pathology; physiology of parasites; general mycology.

Ferguson, J., B.S., M.S., Department of Plant Pathology, University of California, Los Angeles 24, California, U.S.A. (1953.) Soil fungi; antagonism; diseases of ornamental plants.

Ferns, J. F., M.Sc., A.I.C., 16 Lawn Crescent, Kew, Surrey. (1942.)

Fincher, F., Randan Wood, Woodcote, Bromsgrove, Worcs. (1948.) Ecology and periodicity of woodland fungi, esp. Agaricales.

Findlay, W. P. K., D.Sc., A.R.C.S., Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks. (1928.) Polyporaceae and other tree and timber fungi.

Finney, I. D., Balmoral, Edward Road, Forres, Morayshire. (1954.) Larger British agarics; lichens.

Fleetwood, Miss P. M., B.Sc., Department of Botany, The University, Edgbaston, Birmingham 15. (1950.)

Flentje, N. T., B.Agr.Sci., M.Sc., c/o Waite Institute, Private Mail Bag, Adelaide, S. Australia. (1949.)

Fletcher, W. W., B.Sc., Department of Botany, West of Scotland Agricultural College, Blythswood Square, Glasgow, C.2. (1948.) Mycorrhiza; inter-reactions of soil organisms.

Foister, C. E., B.A., Ph.D., Plant Pathology Service, Seed Testing Station, East Craigs, Corstorphine, Edinburgh 12. (1940.) Environmental relations of fungi, esp. pathological activities; phycomycetes, esp. *Phytophthora*, *Pythium*; dispersal and geographical distribution.

Fothergill, P. G., B.Sc., Ph.D., King's College, Newcastle-on-Tyne 2. (1946.)

Fountain, A. S., F.R.M.S., F.R.H.S., 77 Clarendon Road, Fulwood, Sheffield 10. (1954.) Microscopy; botany; zoology; chemistry esp. in relation to microscopy.

Fox, R. A., B.Sc., B.Agric., Rubber Research Institute of Malaya, Pathology Division, P.O. Box No. 150, Kuala Lumpur, Malaya. (1951.)

Francis, Mrs Sheila M., Department of Botany, Imperial College, South Kensington, London, S.W. 7. (1948.) Teaching systematic mycology, esp. field work; plant pathology, Gladiolus diseases.

Fraser, Miss L. R., D.Sc., Biological Branch, Department of Agriculture, Box 36A, G.P.O., Sydney, Australia. (1938.)

Fraymouth, Miss J., Department of Botany, The University, Bristol 8. (1950.)

Fries, Dr N., Institute of Physiological Botany, The University, Uppsala, Sweden. (1946.)

Fulford, R. M., East Malling Research Station, East Malling, Kent. (1949.)

Fulton, D. D. C. (1952.)

Garrett, S. D., M.A., Sc.D., D.I.C., Botany School, Downing Street, Cambridge. (1936.) Root-infecting fungi; plant pathology; soil microbiology.

Gates, L. F., B.A., Rothamsted Experimental Station, Dunholme Field Station, Dunholme, Lincoln. (1947.) Plant pathology.

Gauntlett, Colonel G., 18 Vine Road, East Molesey, Surrey. (1953.)

Gay, J. L., B.Sc., M.Sc., School House, Hartpury, Gloucester. (1952.)

Geddes, J. A., 114 Lucerne Road, Remuera, Auckland, S.E. 2, New Zealand. (1951.)

Gemmell, Professor A. R., B.Sc., Ph.D., M.S., Department of Biology, University College of North Staffordshire, Keele, Stoke-on-Trent, Staffs. (1946.)

Gentles, J. C., B.Sc., Department of Botany, The University of Glasgow. (1948.)

Gibbon, Miss O. M., B.Sc., Red Rice, Timsway, Chertsey Lane, Staines, Middx. (1952.)

Gibson, I. A. S., M.A., The Forest Department, P.O. Box 337, Nairobi, Kenya. (1952.) Seedling diseases; fungicides; antibiotics; forest disease problems.

Glasscock, H. H., Wye College, Wye, Ashford, Kent. (1949.) Plant pathology.

Glen-Bott, Miss J. I., M.Sc., Kinnaird College, Lahore, Pakistan. (1949.) Aquatic fungi; esp. aerial sporing Hyphomycetes.

Glynn, E. St A., 6A Lancaster Drive, London, N.W. 3. (1946.) Inoperculate Discomycetes.

Glynne, Miss M. D., D.Sc., Rothamsted Experimental Station, Harpenden, Herts. (1932.)

Gobie, C. H., B.Sc., F.R.G.S., 4 Melton Court, Amyand Park Road, Twickenham, Middx. (1953.)

Goldie-Smith, Miss E. K., Department of Botany, University of North Carolina, U.S.A. (1944.) Aquatic Phycomycetes; *Actinoplanes* (Actinomycetes).

Goodchild, N. A., B.Sc.Agric., P.O. Box 91, Kericho, Kenya. (1951.)

Goode, Miss P. M., B.Sc., Department of Botany, The University, Edgbaston, Birmingham 15. (1953.) Plant pathology; host-parasite relationships of *Phytophthora fragariae.*

Goodman, R. E. J., Norfolk Flax Establishment, Flitcham Abbey, Flitcham, King's Lynn, Norfolk. (1944.)

Graddon, W. D., B.Sc., A.M.I.Chem.E., Rathgar, Park Lane, Congleton, Cheshire. (1942.) Discomycetes.

Grainger, Miss J., Wilshaw Road, Meltham, nr Huddersfield. (1943.)

Grainger, J., B.Sc., Ph.D., Department of Plant Pathology, West of Scotland Agricultural College, Auchincruive, Ayr. (1944.)

Gray, Miss E. G., B.Sc., Ph.D., North of Scotland Agricultural College, 41½ Union Street, Aberdeen. (1942.) Fungi on *Lolium*; cereal smuts.

Gregg, Miss M., B.Sc., Ph.D., 12 Bushey Park Road, Rathgar, Dublin, Eire. (1948.)

Gregory, Professor P. H., Ph.D., D.Sc., D.I.C., Department of Botany, Imperial College of Science and Technology, South Kensington, London, S.W. 7. (1930.) General mycology; plant pathology; aerobiology.

Griffiths, D. J., M.Sc., Welsh Plant Breeding Station, Aberystwyth. (1951.)

Griffiths, E. G., Agricultural Buildings, Alexandra Road, Aberystwyth. (1948.)

Grossbard, Miss E., Department of Biochemistry, The University of Leeds, 9 Hyde Terrace, Leeds 2. (1948.)

Groves, Dr J. W., Division of Botany and Plant Pathology, Science Service Building, Ottawa, Ontario, Canada. (1942.) Discomycetes; Agaricaceae and Boletaceae; seed-borne fungi.

Gwynne, D. C., N.A.A.S., Plant Pathology Department, Elswick Hall, Elswick Park, Newcastle-on-Tyne 4. (1946.)

Gwynne-Vaughan, Professor Dame H. C. I., G.B.E., D.Sc., LL.D., F.L.S., 93 Bedford Court Mansions, London, W.C. 1. (1906.) Cytology and general mycology.

Hadley, G., B.Sc., Department of Botany, The University, Edgbaston, Birmingham 15. (1954.)

Hafiz, Abdul, Ph.D., D.I.C., M.Sc. (Agric.), Department of Plant Protection, Block 61/1, Pakistan Secretariat, Karachi 1, Pakistan. (1950.) Physiology; smuts and blights.

Hagen, A., M.Sc., Botanical Museum, Oslo, Norway. (1949.) Micromycetes, esp. rust, smuts; arctic botany.

Hainsworth, H. E., M.A., Research Station, Fernhurst, nr Haslemere, Surrey. (1946.)

Hall, Rev. C. A., F.R.M.S., Gables, Sleepy Hollow, nr Storrington, Sussex. (1948.)

Hamilton, Miss Elizabeth D., Imperial College Hostel, Prince Consort Road, S. Kensington, London, S.W. 7. (1953.)

Hams, A. F., B.Sc., A.R.C.S., 37 Swains Avenue, Bakersfields, Nottingham. (1948.)

Hansford, C. G., M.A., F.L.S., Sc.D., Waite Agricultural Research Institute, Private Mail Bag, Adelaide, S. Australia. (1921.) Compilation of Australian fungus flora; Meliolaceae and related foliicolous Ascomycetes; general mycology and taxonomy.

Harley, J. L., M.A., D.Phil., Department of Botany, The University, Oxford. (1932.) Mycorrhiza; soil fungi; ecology of larger fungi.

Harris, G. C. M., B.Sc., M.A., D.Phil. (1946.) Industrial fermentations.

Harris, R. V., D.Sc., A.R.C.S., East Malling Research Station, nr Maidstone, Kent. (1924.)

Harrison, R. W., B.Sc., 121 Wellsway, Bath. (1953.)

Harrold, C. E., B.Sc., Ph.D., Department of Botany, The University, Edgbaston, Birmingham 15. (1951.)

Harthan, Miss B. J., 2 Derbyshire Lane, Stretford, nr Manchester. (1951.)

Harvey, R., B.Sc., Department of Botany, University College, Newport Road, Cardiff. (1951.) Aquatic phycomycetes, particularly endophytic forms; Uredinales, particularly fern rusts.

Haskins, R. H., B.A., M.A., Ph.D., National Research Council, Prairie Regional Laboratory, Saskatoon, Sask., Canada. (1946.) Utilisation of agricultural wastes and surpluses by fungi; Chytridiales; smut fungi in submerged culture; production of enzymes by fungi; preservation and conservation of fungus cultures.

Haslam, R. F., A.R.C.S., B.Sc., 2A Colinette Road, Putney, London, S.W. 15. (1954.) Biochemistry and physiology of fungi.

Hassell, F. C., 8 Sunbury Gardens, Dartry Road, Dublin, S. 2, Eire. (1946.)

Hastings, Somerville, M.S., F.R.C.S., 12 Westminster Palace Gardens, Victoria Street, London, S.W. 1. (1913.) Field mycology and ecology; plant photography.

Hawker, Miss L. E., Ph.D., D.Sc., Department of Botany, The University, Bristol. (1934.) Physiology of spore production; hypogeous fungi.

Hawkins, J. H., B.Sc., M.Sc., Arncliffe Cottage, Arnside, nr Carnforth, Westmorland. (1953.) 'Sooty moulds' and other fungi on leaf and fruit surfaces; disease in horticultural plants; pyrenomycetes; aquatic phycomycetes (not chytrids).

Hay, Miss J. M., B.Sc., East Malling Research Station, nr Maidstone, Kent. (1953.) Plant pathology.

Heath, L. A. F., B.Sc., 3 Sunny Hill, London, N.W. 4. (1955.) Soil microbiology; plant pathology.

Heimbeck, Mrs L., Brosoe, Levanger, Norway. (1923.) L. forms of bacteria as plant parasites.

Hemming, H. G., Imperial Chemical Industries Ltd., Akers Research Laboratories, The Frythe, Welwyn, Herts. (1946.)

Henderson, D. M., Royal Botanic Gardens, Inverleith Row, Edinburgh. (1951.)

Herd, G. W., c/o Division of Agriculture and Lands, Branch of Botany and Plant Pathology, P.O. Box 100, Causeway, Salisbury, S. Rhodesia. (1952.)

Herd, Miss S. J., B.Sc., Wellbrae, Bankwell Road, Anstruther, Fife. (1947.) Industrial mycology, esp. antibiotic and yeast production; culture, plant cleaning and sterilization problems.

Hesseltine, C. W., B.A., Ph.D., Northern Regional Research Laboratory, Peoria, Illinois, U.S.A. (1948.) Mucorales; *Streptomyces*; antibiotics and other industrial fermentations; growth factors.

Hewett, P. D., 14 Nansen Avenue, Poole, Dorset. (1947.)

Hewlett, Margaret A., B.Sc., 3 Upperton Road, Sidcup, Kent. (1953.)

Hickman, C. J., B.Sc., M.Sc., Ph.D., Department of Botany, The University, Edgbaston, Birmingham 15. (1935.) Mycology; plant pathology.

Hidaka, Dr Z., Department of Plant Pathology, Hatano Tobacco Experiment Station, Hatano, Kanagawa, Japan. (1951.)

Hilton, R. N., B.A., Rubber Research Institute of Malaya, P.O. Box 150, Kuala Lumpur, Malaya. (1948.)

Hincks, W. D., M.Sc., F.R.E.S., A.M.A., Manchester Museum, The University, Manchester 13. General mycology; entomogenous fungi. (1951.)

Hinson, W. H., B.Sc., Ph.D., Forestry Commission, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey. (1950.)

Hirst, J. M., D.Sc., B.Sc., Rothamsted Experimental Station, Harpenden, Herts. (1949.) Epidemiology of 'air-borne' plant pathogens (esp. *Phytophthora infestans*); relation of fungal activity to weather; spore trapping methods; diseases of potato; apple scab; rust fungi.

Hiscott, G. S., Furzy Grove, Kempshott Lane, Basingstoke, Hants. (1944.)

Hof, Dr T., Centraal Instituut voor Materiaalonderzoek, Rijswijk (Bij Delft), Lange Kleiweg 22, Holland. (1947.)

Holden, Miss M., B.Sc. (1950.) Agaricaceae and Boletaceae.

Holliday, P., M.A., Imperial College of Tropical Agriculture, St Augustine, Trinidad, British West Indies. (1948.) Fungus diseases of cocoa and tropical tree crops; Nectriaceae.

Holmes, G. D., Forestry Commission, Alice Holt Lodge, Wrecclesham, Farnham, Surrey. (1947.)

Holmes, Mrs S. E., B.Sc., Vicarage Flat, Holy Trinity, Cookham, Berks. (1952.)

Hopkins, J. C. F., D.Sc., A.I.C.T.A., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1953.) Tropical plant diseases, *Alternaria*.

Hora, Dr F. B., The University, Reading, Berks. (1943.)

Howard, E., B.Sc. (1953.)

Howard, H. J., F.R.M.S., F.R.P.S., F.L.S., Lingfield, 6 College Road, Norwich. (1918.) Myxomycetes; microscopy, photomicrography and photography.

Howe, F. J., F.R.M.S., F.R.E.S., F.I.M.L.T., Pathological Department, St Cross Hospital, Rugby, Warwickshire. (1943.) Medical mycology.

Hudson, H. J., B.Sc., Botany Department, The University, Sheffield 10. (1955.) Ecology of fungi occurring on grasses.

Hughes, S. J., M.Sc., Division of Botany and Plant Pathology, Department of Agriculture, Ottawa, Ontario, Canada. (1941.)

Hughes, W. A., B.Sc., East of Scotland College of Agriculture, Edinburgh. (1952.) Applied mycology; photography of pathological specimens; club-root of Brassicas.

Huijsmann, Dr H. S. C., Oogarts, Doetinchem, Holland. (1947.) Agaricales.

Hull, R., B.Sc., Ph.D., A.R.C.S., c/o Rothamsted Experimental Station, Field Research Station, Hackthorn, Lincoln. (1942.)

Humphreys-Jones, Dr R., Newfields, Beaumont Rise, Marlow, Bucks. (1952.)

Hutchings, G. E., Juniper Hall Field Centre, Dorking, Surrey. (1948.)

Hutchinson, J. M., B.Sc., c/o John and E. Sturge, Ltd., Denison Road, Selby, Yorks. (1954.) Penicillia and Aspergilli (esp. *A. niger*).

Hutchinson, P. B., M.Sc., Imperial College of Tropical Agriculture, Trinidad, British West Indies. (1951.) Tropical plant pathology.

Hutchinson, S. A., T.D., B.Sc., Ph.D., Department of Botany, The University, Glasgow. (1948.) Ecology of micro-fungi; antibiotics; carboniferous fossil fungi.

Ingold, Professor C. T., D.Sc., Ph.D., F.L.S., Department of Botany, Birkbeck College, Malet Street, London, W.C. 1. (1935.) Spore dispersal; aquatic fungi, esp. chytrids; Hyphomycetes and Ascomycetes.

Ives, Miss J., B.Sc., 26 Woodlark Road, Cambridge. (1949.) Plant pathology, esp. diseases of potatoes and legumes; *Botrytis*; agarics.

Jackson, R. M., Department of Agriculture, University College, Ibadan, Nigeria, W. Africa. (1946.)

Jacques-Félix, Madame M., 68 rue François Rolland, Nogent-sur-Marne (Seine), France. (1952.)

Jarvis, W. R., B.Sc., Ph.D., Scottish Horticultural Research Institute, Mylnefield, Invergowrie, By Dundee, Angus. (1951.) Physiology of parasitism, esp. pectic enzyme systems of soft-rotting organisms; pathogenicity of *Phytophthora fragariae*.

Jay, B. A., M.A., F.L.S., 9 Thornton Crescent, Old Coulsdon, Surrey. (1946.) Wood-destroying and staining fungi; larger British fungi; edible fungi.

Jeffreys, E. G., M.A., Imperial Chemical Industries, Ltd., Akers Research Laboratories, Welwyn, Herts. (1946.) Antibiotics; soil microbiology; ecology of micro-organisms in some industrial fermentation; morphology of moulds in industrial fermentation; physiology.

Jenkins, Miss A. E., Institute of Inter-American Affairs, Research Specialist in Plant Pathology, c/o American Consulate, São Paulo, Brazil. (1942.)

Jenkins, J. E. E., B.Sc., c/o N.A.A.S., 33 Turners Hill, Cheshunt, Herts. (1949.) Plant pathology, esp. in glasshouse crops.

Johns, R. M., Department of Botany, The University, Michigan, U.S.A. (1954.)

Johnstone, R. H., M.A., 726 Anniesland Road, Glasgow, W. 4. (1938.) Higher fungi, esp. agarics.

Jones, D. Rudd, M.A., Ph.D., Imperial Chemical Industries, Ltd., Akers Research Laboratories, The Frythe, Welwyn, Herts. (1949.)

Jones, Miss E. S. L., Syracuse, High Cross Lane, Newport, Mon. (1950.)

Jones, F. G. B., M.A., 32 Kingston Lane, Teddington, Middx. (1949.) Discomycetes, esp. their physiology; teaching of mycology.

Jørstad, Ivar, Statsmykolog, Botanisk Museum, Oslo, Norway. (1923.)

Juniper, A. J., B.Sc., F.L.S., F.Z.S., 50 Dawlish Drive, Ilford, Essex. (1951.) Predacious fungi.

Justham, Mrs M. C. D., Ph.D., Cherry Dene, Cairn Road, Bielside, Abedeen. (1945.)

Kamel, Mostafa, B.Sc., M.Sc., Ph.D., Botany Department, Faculty of Agriculture, Giza, Egypt. (1954.) Antibiotics.

Kaung, Zan, B.Sc., Botany Department, Imperial College of Science and Technology, South Kensington, London, S.W. 7. (1954.)

Keay, Miss M. A., M.A., Ph.D., Makerere College, University College of East Africa, P.O. Box 262, Kampala, Uganda, E. Africa. (1935.)

Keeping, Dr E. S., Provincial Laboratory, University of Alberta, Edmonton, Alberta, Canada. (1950.)

Kennedy, Miss M. E., B.Sc., M.Sc., Hartley Botanical Laboratories, The University, Liverpool. (1951.)

Kent, W. W., Red House, Rodbourne, Swindon, Wilts. (1948.)

Kerr, A., B.Sc., Waite Agricultural Research Institute, Adelaide, South Australia. (1948.)

Kertland, Miss M. P. H., M.Sc., Department of Botany, Queen's University, Belfast, N. Ireland. (1948.)

Keys, Mrs V. (1952.)

Keyworth, W. G., Ph.D., D.I.C., National Vegetable Research Station, Wellesbourne, Warwick. (1941.)

Kharbouch, M. A. M., B.Sc., Ph.D., Department of Botany, The University, Alexandria, Egypt. (1951.)

Kind, S. S., B.Sc., Flat 1, 33 Kent Road, Harrogate, Yorks. (1952.) Physiology and biochemistry of fungi.

Klein, R., Ph.D., F.L.S., 1 Emperors Gate, London, S.W. 7. (1943.)

Knapman, Miss J., Penn Sylva, Hele Manor, Barnstaple, N. Devon. (1952.)

Knight, B. C., B.Sc., North of Scotland College of Agriculture, 41½ Union Street, Aberdeen. (1951.) Club-root of Brassicas; potato storage problems; diseases of horticultural crops.

Knowles, R., B.Sc., Department of Botany, University College, London, W.C. 1. (1953.) Soil microbiology.

Knoyle, Miss M., M.Sc., Glaxo Laboratories, Sefton Park, Slough, Bucks. (1954.)

Korf, Professor R. P., B.Sc., Ph.D., Department of Plant Pathology, Cornell University, Ithaca, N.Y., U.S.A. (1947.) Discomycetes, esp. Pezizales and Hyaloscyphaceae; nomenclature; phylogeny of Ascomycetes; teaching.

Kramer, L. M. J., M.A., Ph.D., 41 Marlborough Mansions, Cannon Hill, London, N.W. 6. (1946.)

Krebs, Mrs L., 42 Selcroft Road, Purley, Surrey. (1948.)

Langdon, R. F. N., M.Agr.Sci., Ph.D., Department of Botany, University of Queensland, George St., Brisbane, Australia. (1950.) Teaching of mycology and plant pathology; Ustilaginales; Fungi Imperfecti; geographic distribution of fungi.

Lange, M., Dr.Phil., Universitets Planteanatomiske Laboratorium, Gothersgade 140, Copenhagen, Denmark. (1949.) Agarics and gasteromycetes; hypogeous fungi; ecology of fleshy fungi; fungi of arctic and alpine regions.

Lapwood, D. H., A.R.C.Sc., D.I.C., Ph.D., 2 Greenways, North Road, Hertford, Herts. (1935.) Pectinase secreting fungi.

Large, E. C., Plant Pathology Laboratory, Milton Road, Harpenden, Herts. (1948.)

Last, F. T., Rothamsted Experimental Station, Harpenden, Herts. (1949.) Physiology, esp. of obligate parasites; leaf diseases of cereals, esp. powdery mildews.

La Touche, C. J., M.Sc., L.A.H., Department of Bacteriology, Medical School, The University, Leeds. (1946.)

Leach, R., B.A., School of Agriculture, Cambridge. (1929.)

Leather, R. I., B.Sc., Wharfecote, Benrhydding, Ilkley, W. Yorks. (1952.)

Lee, O. M., School of Agriculture, Serdang, Selangor, Malaya. (1946.)

Lee-Whiting, Mrs B. B., B.Sc., Ph.D., 6 Huron Street, Deep River, Ontario, Canada. (1950.) Sclerotia; rhizomorphs; genetics of yeasts.

Le Gal, Mme Marcel, Laboratoire de Cryptogamie, Muséum National d'Histoire Naturelle, 12 rue de Buffon, Paris, France. (1948.)

Lelliott, R. A., B.A., 138 Top Street Way, Harpenden, Herts. (1952.)

Lester, E., B.Sc., N.A.A.S., Shardlow Hall, Shardlow, nr Derby. (1948.) Diseases of plants; Fungi Imperfecti; Phycomycetes; technical methods.

Levisohn, Miss I., D.Phil., Bedford College for Women, Regent's Park, London, N.W. 1. (1943.)

Lloyd, Blodwen, M.Sc., Ph.D., Royal Technical College, Glasgow, C. 1. (1946.) Denitrifying bacteria; marine bacteria; nitrogen fixation; cine-films in mycology and bacteriology.

Lloyd, Mrs J. W., B.Sc., Ph.D., 63 Charnock Avenue, Wollaton Park, Nottingham. (1949.) Pyrenomycetes; conidia of Hymenomycetes.

Locquin, M., Muséum National d'Histoire Naturelle, 12 rue de Buffon, Paris, France. (1950.)

Lodhi, S. A., M.Sc., Department of Botany, University of the Punjab, Lahore, Pakistan. (1950.)

Lofts, Miss M. J., Nigerian College of Art, Science and Technology, Ibadan, Nigeria. (1947.)

Lohwag, Professor K., Rennweg 2, Vienna III, Austria. (1950.) Forest pathology and timber decay.

Loos, C. A., Tea Research Institute, St Coombs, Talawakelle, Ceylon, (1952.)

Lowings, P. H., B.Sc., B.Agr., Ph.D., Ditton Laboratory, East Malling, nr Maidstone, Kent. (1951.) Plant pathology, esp. cereal diseases caused by *Fusarium*; *Fusarium* taxonomy.

Luc, M., Institut Intercolonial d'Adiopodoum, Boîte Postale 20, Abidjan, Côte d'Ivoire. (1951.)

Lucas, R. L., M.A., Ph.D., Department of Agriculture, The University, Oxford. (1949.) Plant pathology, esp. root-infecting fungi.

Lupton, F. G. H., M.A., Plant Breeding Institute, Maris Lane, Trumpington, Cambridge. (1952.) Breeding cereals for disease resistance; parasitism of *Puccinia* and *Erysiphe*.

Lütjeharms, Professor W. J., Phil.Nat.D., Department of Botany, University of Bloemfontein, Orange Free State, S. Africa. (1930.)

MacDonald, J. A., D.Sc., Ph.D., F.R.S.E., Botany Department, The University, St Andrews. (1938.)

MacKinnon, Juan E., M.D., Instituto de Higiene, Av. A. Ricaldoni 3051, Montevideo, Uruguay. (1947.) Medical and veterinary mycology.

McIlwaine, R. S., Department of Plant Pathology, Queen's University, Belfast. (1951.) General Mycology.

McKay, Professor R., D.Sc., A.R.C.Sc.I., Albert Agricultural College, Glasnevin, Dublin. (1939.) General plant pathology.

McKee, R. K., Nottingham University School of Agriculture, Sutton Bonington, Loughborough, Leics. (1947.)

McTeague, Dorothy M., B.Sc., 2 Sydenham Road, Glasgow, W. 2. (1954.)

Madelin, M. F., Flat 7, 19 Lee Terrace, Blackheath, London, S.E. 3. (1950.) Physiology of fruiting in Hymenomycetes, esp. of *Coprinus lagopus*; nutrition of fungi; Hyphomycetes.

Madge, Miss M. A. P., Ph.D., Royal Holloway College, Englefield Green, Surrey. (1948.)

Mahoney, Monica F., B.Sc., Cardonald, Primrose Ridge, Godalming, Surrey. (1953.)

Main, Mrs S. M., B.Sc., F.L.S., 143 Oaklands Avenue, Oxley, Herts. (1950.) Predacious fungi; biological control of nematodes.

Malcolmson, Miss J. F., 25 Coillesdene Drive, Portobello, Midlothian. (1952.)

Malençon, G., Inspecteur Principal, Bureau de la Défense Végétaux, 65 bis Avenue de Témara, Rabat, Morocco. (1946.)

Malone, J. P., B.Sc., Department of Mycology and Plant Pathology, Queen's University, Belfast, N. Ireland. (1948.)

De Man, G., 37 Av. des Mimosas, Woluwé St Pierre, Brussels, Belgium. (1951.)

Mangenot, Professor F., Institut de Botanique, 30 bis, rue Sainte Catherine, Nancy, M. & M., France. (1953.) Phytopathology; Fungi Imperfecti; Ascomycetes.

Manners, J. G., M.A., Ph.D., Botany Department, The University, Southampton. (1948.) Rust fungi; mechanism of susceptibility and resistance to fungal attack; tree cankers, esp. larch canker.

Marcan, Mrs B., 415 West Wycombe Road, High Wycombe, Bucks. (1948.)

Marsh, R. W., M.A., Research Station, Long Ashton, Bristol. (1923.) Diseases of fruit crops; fungicides.

Martens, P., Dr.Sc., Professeur à l'Université, 28 Rue Marie-Thérèse, Louvain, Belgium. (1947.) Cytology.

Martin-Scott, I., M.D., 16 Buckingham House, Courtlands, Richmond, Surrey. (1948.)

Mason, E. W., M.A., M.Sc., F.L.S., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1921.)

Mason, Mrs E. W., M.Sc., Inglenook, 63 King's Road, Richmond, Surrey. (1922.)

Maude, R. B., B.A., M.Sc., St Finan's, Swords, Co. Dublin, Ireland. (1954.)

Maxted, Mrs B., B.Sc., Ph.D., Department of Botany, The University, Reading, Berks. (1934.)

Melin, Professor J. B. E., Institute of Physiological Botany, Uppsala, Sweden. (1946.)

Mence, Miss M. J., School of Agriculture, University College of North Wales, Bangor, Caern. (1948.)

Menzies, Miss B. P., M.Sc., Ph.D., Department of Botany, Bedford College, Regent's Park, London, N.W. 1. (1948.) Life history of systemic rusts, esp. nuclear changes; inhibitory effect of tropolones on growth of fungi.

Milet, J. W., A.I.M.L.T., c/o Department of Pathology, Westmorland County Hospital, Kendal, Westmorland. (1955.) Medical bacteriology; biochemistry and histology; general mycology.

Miller, Professor J. H., B.S., M.S., Ph.D., University of Georgia, Athens, Georgia, U.S.A. (1930.)

Mishra, J. N., Ph.D., Plant Pathologist, Bihar Government, Sabour, Bhagalpur, India. (1954.)

Montgomerie, Miss I. G., B.Sc., Ph.D., Scottish Horticultural Research Institute, Auchincruive, Ayr. (1951.) Physiological specialixation in fungi; red core of strawberries; *Phytophthora* and *Pythium*.

Montgomery, Mrs N., Chelmsley, Tollerton Lane, Tollerton, Notts. (1949.)

Moon, J. McK., 24 Brookvale Avenue, Belfast, N. Ireland. (1948.)

Moore, Miss F. J., Ph.D., Ministry of Agriculture, Plant Pathology Laboratory, Milton Road, Harpenden, Herts. (1945.) Plant pathology, esp. pathogenic fungi.

Morquer, Professor R., Faculté des Sciences, Laboratoire de Botanique Générale, Toulouse, France. (1951.)

Morris, L. E., c/o Eton College, Windsor, Berks. (1924.)

Morris, P. E., B.Sc., D.I.C., M.R.I.P.H.H., Fernside, Ormesby St Margaret, Norfolk. (1950.)

Morton, A. G., B.Sc., Ph.D., Imperial Chemical Industries, Akers Research Laboratories, The Frythe, Welwyn, Herts. (1955.) Physiology; higher Basidiomycetes.

Moser, M., Innsbruck, Müllerstrasse 9, Austria. (1949.)

Munro, H. R., 93 Green Meadow Road, Selly Oak, Birmingham 29. (1948.)

Munson, R. G., 29 Northwick Circle, Kenton, Harrow, Middx. (1943.)

Murray, J. S., B.Sc., Forestry Commission, Alice Holt Lodge, Wrecclesham, Farnham, Surrey. (1950.) Forest pathology.

Muskett, Professor A. E., D.Sc., A.R.C.S., M.I.Biol., M.R.I.A., The Queen's University, Belfast. (1923.) General mycology and plant pathology; seed-borne fungi; Irish fungal flora.

Nannfeldt, Professor J. A., Institute of Systematic Botany, University of Uppsala, Sweden. (1932.) Morphology and taxonomy of Micromycetes, esp. Discomycetes; phylogeny.

Nash-Wortham, J. R. H., F.L.S., 9 Harrington Road, Preston Park, Brighton 6, Sussex. (1937.) Fungi causing wastage in cold stored fruit and vegetables; colour transparencies of agarics and boleti.

Nattrass, R. M., B.Sc., Ph.D., Department of Agriculture, P.O.B. 338, Nairobi, Kenya. (1925.)

Nelson, J. D. E., B.Sc., Glaxo Laboratories, Ltd., Ulverston, Lancs. (1952.) Wood fungi, esp. bracket forms, distribution, and preservation; antibiotics.

Newby, H. V., Department of Botany, Queen Mary College, London, E. 1. (1946.)

Newhook, F. J., M.Sc., Ph.D., D.I.C., Plant Diseases Division, D.S.I.R., Private Bag, Auckland, New Zealand. (1946.)

Nicholls, Miss V. O. (Mrs Sankey), Department of Botany, University of London, King's College, 68 Half Moon Lane, Herne Hill, London, S.E. 24. (1949.) Soil microbiology; rhizosphere; mycorrhiza; general pathology; ecology of higher fungi.

Nicolson, T. H., B.Sc., School of Agriculture, Sutton Bonington, Loughborough, Leics. (1954.) Plant pathology; root-infection by fungi of a mycorrhizal type in the Gramineae.

Nobbs, Miss G. E. D., 4 Clifton Estate, Plympton, S. Devon. (1943.)

Noble, Miss M., B.Sc., Ph.D., 19A Willowbrae Avenue, Edinburgh 8. (1940.) Seed Pathology.

Nobles, Dr Mildred K., B.A., M.A., Ph.D., Botany and Plant Pathology Division, Science Service Buildings, Ottawa, Ontario, Canada. (1953.) Wood-inhabiting Hymenomycetes.

Norman, Miss T., B.Sc., N.A.A.S., Elswick Hall, Elswick Park, Newcastle-upon-Tyne 4. (1953.)

Nour, Mohamed A., B.Sc., Faculty of Agriculture, Shambat, Sudan. (1951.) Plant pathology, esp. tropical; powdery mildews.

O'Connor, P., Ph.D., B.Sc., A.R.C.Sc.I., National Museum, Dublin. (1925.)

Ogilvie, L., M.A., B.Sc., M.Sc., Plant Pathology Department, Ministry of Agriculture, Westbury on Trym, nr Bristol. (1922.) Economic plant diseases.

Oliver, A. C., B.Sc., M.Sc., Tynron, Goring Road, Goring-by-Sea, Sussex. (1955.) Pathology; morphology and classification; forays.

Olivier, Miss D. L., Department of Botany, Rondebosch University, Cape Province, S. Africa. (1950.)

Orton, P. D., M.A., A.R.C.M., Epsom College, Epsom, Surrey. (1947.) Agaricology, esp. the coloured spore groups; taxonomy.

Owen, H., B.Sc., A.I.C.T.A., Department of Agricultural Botany, The University, Reading. (1950.)

Padwick, Dr G. W., Imperial Chemical Industries Ltd., Nobel House, 2 Buckingham Gate, London, S.W. 1. (1936.)

Page, Miss W. M., M.Sc., Ph.D., F.L.S., 5 Dartmouth Chambers, Theobald's Road, London, W.C. 1. (1921.) Coprophilous pyrenomycetes.

Palmer, J. T., 5 Station Road, Woodley, Stockport, Cheshire. (1950.) Gasteromycetes; general mycology, esp. larger fungi.

Park, D., M.Sc., Department of Botany, The University, Manchester 13. (1954.) Soil microbiology; mycorrhiza; fungal ecology.

Parker, H. M., B.Sc., C.D.A., 92 (Lower Flat), High Street, Girton, Cambridge. (1949.) Plant pathology; Uredinales.

Parker-Rhodes, A. F., 20 Sedley Taylor Road, Cambridge. (1950.) Eubasidiomycetes, esp. ecology and taxonomy.

Parkinson, D., B.Sc., Department of Botany, Royal Holloway College, Englefield Green, Surrey. (1950.) Ecology of soil fungi; physiology of soil micro-organisms; aquatic fungi.

Paterson, R. A., B.A., M.A., Department of Botany, University of Michigan, Ann Arbor, Michigan, U.S.A. (1954.) Fungal parasites of plankton, and their ecological significance; aquatic phycomycetes.

Paton, Miss M. R., Barnbarroch House, Dalbeattie, Scotland. (1945.)

Peach, Mrs M., B.Sc., Ph.D., 121 Coombe Lane, West Wimbledon, London, S.W. 20. (1947.) Aquatic fungi, esp. predacious fungi; fungi attacking eelworm cysts.

Pegg, G. F., B.Sc., M.Sc., Department of Biological Sciences, Wye College, nr Ashford, Kent. (1952.)

Perrott, Mrs P. E., M.Sc., University College of North Staffordshire. (1945.) Aquatic Phycomycetes, esp. Monoblepharidales.

Perry, B. J., 7 Church Street, Exmouth, S. Devon. (1954.) Plant pathology; general mycology.

Perry, D. A., 385 Reddings Lane, Birmingham 11. (1954.) General mycology, esp. pathology; photography.

Peters, J. H., B.Sc., 64 Salisbury Street, Bedford. (1953.) Discomycetes.

Pettifer, A. J., Whytegates, Pear Tree Lane, Danbury, Essex. (1944.)

Peyronel, Professor B., Directeur, Istituto & Orto Botanico, Viale Mattioli 25 (Valentino), Torino, Italy. (1932.) Mycorrhiza; soil fungi; Phycomycetes.

Philips, D. H., M.Sc., 2 La Mabonnerie, States Farm, Trinity, Jersey, Channel Islands. (1950.) Plant pathology; soil mycology; Uredinales.

Piane, V., Martignat (Ain), France. (1952.)

Pilat, Dr A., Department of Botany, National Museum, Prague II, Václavské nám. 1700, Czechoslovakia. (1946.) Basidiomycetes; lignicoli.

Ping, A. Wentworth, M.A., Lowfields, 8 Galtres Road, Clifton Without, York. (1926.)

Pinto-Lopes, Professor Dr J., Faculdade de Ciências, Lisboa, Portugal. (1949.) Polyporaceae; taxonomy; biology; didactics.

Platt, J., B.Sc., The Chestnuts, 2 St Andrews Road, Burnham-on-Sea, Somerset. (1947.) Higher fungi.

Plunkett, B. E., B.Sc., Ph.D., 31 Priory Avenue, London, N.8. (1945.) Physiology of reproduction and fruit-body development, esp. in hymenomycetes; teaching.

Pollard, H. B. C., Whitelands, Hollist Lane, Midhurst, Sussex. (1949.)

Porter, Mrs L., M.Sc., Summerfield, Dalkey Avenue, Dalkey, Co. Dublin, Eire. (1949.) Lichens.

Porter, S. C., A.R.I.C., A.M.I.Chem.E., 57 Billesley Lane, Moseley, Birmingham 13. (1946.) Larger fungi; photography.

Prentice, I. W., B.Sc., Ph.D., Ministry of Agriculture, Plant Pathology Laboratory, Milton Road, Harpenden, Herts. (1943.) Plant pathology.

Preston, N. C., B.Sc., N.A.A.S., Woodthorne, Wolverhampton, Staffs. (1920.)

Price, E. A. S., B.A., Hastings House, Ledsham, South Milford, Yorks. (1953.)

Price, J. W., The Moor, Eardiston, nr Tenbury, Worcs. (1952.)

Priest, D., 308 Hither Green Lane, Lewisham, London, S.E. 13. (1952.)

Prowse, G. A., B.Sc., Ph.D., 40 Devonshire Hill Lane, Tottenham, London, N. 17. (1949.) Aquatic fungi, esp. Lagenidiales and Chytridiales; predacious fungi, esp. aquatic.

Pugh, G. J. F., B.Sc., Ph.D., Department of Botany, The University, Nottingham. (1952.)

Quick, A. H., B.Sc., A.R.I.C., Department of Science, Mining and Technical College, Barnsley, Yorks. (1952.)

Rapson, Mrs H., Flat 3, Bockham Park, Betchworth, Surrey. (1950.)

Rautavaara, Toivo, D.Sc., Mannerheimint 56, B 15, Helsinki, Finland. (1949.) Biology, esp. of larger fungi; culture of edible mushrooms; mycoflora of soils, etc.; fungus diseases of plants.

Rayner, R. W., Box 4333, Nairobi, Kenya, E. Africa. (1952.) Macrofungi, esp. of Africa; fungal diseases of coffee.

Rees, Mrs J., B.Sc., M.Sc., 1 Hall Avenue, Mexborough, Yorks. (1950.) Basidiomycetes; pathology.

Reid, D. A., B.Sc., 17 Lower King's Road, Berkhamsted, Herts. (1950.)

Richards, M., M.A., M.Sc., Ph.D., F.L.S., National Research Council, Prairie Regional Laboratory, Saskatoon, Sask., Canada. (1950.) Aquatic Chytridiales; Hyphomycetes; airborne fungal spores and allergy.

Riddell, R. W., M.D., M.R.C.P., Department of Medical Mycology, Institute of Dermatology, St John's Hospital for Diseases of the Skin, Lisle Street, Leicester Square, London, W.C. 2. (1950.) Medical mycology.

Rishbeth, J., M.A., Ph.D., Botany School, Downing Street, Cambridge. (1955.) Bacterial diseases; forest pathology; vascular wilts.

Ritson, W., 12 West Street, Winwick Road, Warrington, Lancs. (1946.)

Roberts, E. T., B.Sc., A.R.C.S., N.A.A.S., Chiltern Court, St Peter's Avenue, Caversham, Reading, Berks. (1947.)

Roberts, Miss F. M., Ph.D., 1 King Street, Montego Bay, Jamaica. (1948.)

Roberts, Miss M., 7 Manson Place, London, S.W.7. (1949.)

Robertson, A. G., B.Sc., 2 Westfield Park, Redland, Bristol. (1948.)

Robertson, Miss A. L. C., B.Sc., Distillers Co. (Biochemicals) Ltd., Fleming Road, Speke, Liverpool 19. (1954.)

Robertson, N. F., B.Sc., M.A., Ph.D., Botany School, Downing Street, Cambridge. (1945.) General mycology and plant pathology.

Robinson, E., Byways, Newton Poppleford, Sidmouth, Devon. (1938.)

Robson, Mrs J. E., B.Sc., St Margaret's House, Great Gaddesden, nr Hemel Hempstead, Herts. (1953.) Yeasts, esp. *Candida* and pathogenic fungi; genetics of these organisms.

Rogers, Dr D. P., New York Botanical Garden, Bronx Park, New York 58, N.Y., U.S.A. (1943.) Lower basidiomycetes; mycological bibliography and nomenclature.

Rogerson, C. T., B.Sc., Ph.D., Department of Botany and Plant Pathology, Kansas State College, Manhattan, Kansas, U.S.A. (1947.) Hypocreales, esp. the *Hypomyces-Hypocrea* complex; parasitic fungi on grasses, cereals and ornamental plants; teaching.

Roscoe-Abbott, Capt. J., B.Sc., The School House, Withern, Alford, Lincs. (1946.)

Rose, H. V., Morden College, Blackheath, London, S.E.3. (1944.)

Rosser, W. R., 15 Knox Road, Blakenhall, Wolverhampton. (1950.)

de Rousset-Hall, O., M.A., 44 Great Bowden Road, Market Harborough, Leics. (1942.)

Roy, R. Y., Benares, Hindu University, India. (1947.)

Sadasivan, Professor T. S., M.Sc., Ph.D., F.A.Sc., The University Botany Laboratory, Madras 5, India. (1954.) Plant pathology, esp. soil-borne diseases of plants.

Salt, G. A., M.A., Plant Pathology Department, Rothamsted Experimental Station, Harpenden, Herts. (1946.)

Sampson, Miss K., M.Sc., Malmsmead, Lacey Green, nr Aylesbury, Bucks. (1920.) Ustilaginales; diseases of grasses and herbage legumes.

Samuel, G., M.Sc., Agricultural Research Council, Cunard Building, 15 Regent Street, London, S.W.1. (1923.) General plant pathology.

Sansome, Mrs E. R., M.Sc., Botanical Department, The University, Ibadan, Nigeria. (1945.)

Sarazin, A., 142 Boulevard Maurice Berteaux, Carrières-sur-Seine (S. et O.), France. (1951.)

Savile, D. B. O., Ph.D., M.Sc., B.S.A., Laboratory of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Ontario, Canada. (1954.) Rust and smut fungi, esp. arctic and alpine; phylogeny of hosts and parasites.

Savory, J. G., B.Sc., Forest Products Research Laboratory, Princes Risborough, nr Aylesbury, Bucks. (1946.) Lignicolous fungi, esp. micro-fungi of economic importance.

Schimmer, F. C., M.Sc., D.I.C., Wye College, Ashford, Kent. (1943.) Plant pathology, esp. *Verticillium* wilt of tomato and seed-borne diseases of cauliflower.

Scott, M. R., B.Sc., Department of Botany, The University, Edgbaston, Birmingham 15. (1951.)

Scott, W. W., B.A., M.S., Department of Botany, University of Michigan, Ann Arbor, Michigan, U.S.A. (1954.) Saprolegniaceae; Aphanomyces; aquatic Phycomycetes.

Sewell, G. W., B.Sc., 69 Berrylands Road, Surbiton, Surrey. (1952.) Soil mycology; ecology of soil microfungi.

Shaffer, R. L., B.S., M.S., Department of Plant Pathology, Cornell University, Ithaca, New York, U.S.A. (1953.)

Shaw, C. G., M.A., M.S., Ph.D., Department of Plant Pathology, State College of Washington, Pullman, Washington, U.S.A. (1954.) Peronosporaceae; forest pathology, esp. wood decay fungi; fungi of the Pacific Northwest; fume damage (fluorine).

Shear, Dr C. L., 1707 North Sixth Street, Monroe, Louisiana, U.S.A. (1930.)

Sheard, Mrs E., Fairfield Farm, Esprick, nr Kirkham, Lancs. (1937.)

Shephard, Miss M. C., B.Sc., 115 Sheringham Avenue, Southgate, London, N. 14. (1954.)

Shepherd, Miss A. M., School of Agriculture, Cambridge. (1951.)

Singer, R., Ph.D., Instituto Miguel Lillo, Miguel Lillo 205, Tucumán, Argentina. (1954.)

Sisley, C., Cuprinol Ltd., Terminal House, Grosvenor Gardens, London, S.W. 1. (1947.)

Skene, Professor M., Department of Botany, The University, Bristol. (1936.)

Smith, C. E. D., B.Sc., Woods Mill, Henfield, Sussex. (1949.) Soil fungi; plant pathology; fungicides; fungal ecology.

Smith, G., M.Sc., F.R.I.C., London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C. 1. (1936.) Taxonomy, esp. of Hyphomycetales; biochemistry of moulds.

Smith, H. C. (1951.)

Smith, J. D., B.Sc., Manor Farm House, Cottingley, Bingley, Yorks. (1955.) Diseases of grasses, esp. of turf; testing fungicides; photography of fungi.

Smith, Professor N. J. G., M.A., B.Sc., Ph.D., c/o Barclays Bank, 1 Cockspur Street, London, S.W. 1. (1924.) *Helminthosporium* and *Rhynchosporium* diseases of cereals; mycorrhiza; S. African Gasteromycetes.

Snow, D., Ph.D., Department of Agricultural Botany, The University, Reading. (1947.)

Snyder, Professor W. C., Department of Plant Pathology, University of California, Berkeley 4, California, U.S.A. (1954.)

Sobels, Johanna C., Ph.D., Botanisch Laboratorium, Lange Nieuwstraat 106, Utrecht, Holland. (1953.) Physiology of Myxomycetes.

Sowter, F. A., F.L.S., 9 North Avenue, Leicester. (1942.) Lichens; general mycology; Myxomycetes.

Sparrow, Dr F. K., B.S., M.A., Ph.D., Department of Botany, University of Michigan, Ann Arbor, Michigan, U.S.A. (1946.) Aquatic Phycomycetes; *Physoderma.*

Spence, J., B.Sc., 10A Ellerslie Park, St Clair, Port of Spain, Trinidad, British West Indies. (1951.)

Spilsbury, J. F., B.Sc., W.P.R.L., Langley Court, Beckenham, Kent. (1946.)

Sreeramulu, T., M.Sc., F.B.S., Department of Botany, Imperial College of Science and Technology, South Kensington, London, S.W. 7. (1954.) Systematic mycology; general plant pathology; spore dispersal.

Stakman, Professor E. C., Ph.D., Hon.Dr.Nat.Sci.Germany, D.Sci., St Paul Campus, University of Minnesota, St Paul, Minnesota, U.S.A. (1922.) Plant pathology; general mycology.

Stamps, Miss D. J., B.Sc., Ph.D., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1948.) Phycomycetes, esp. *Phytophthora.*

Stenton, H., University College, Hull. (1948.)

Stephens, Miss E. L., B.A., Department of Botany, University of Cape Town, Cape Town, S. Africa. (1928.) Basidiomycetes; Gasteromycetes; larger Ascomycetes.

Stevenson, Dr J. A., 4113 Emery Place, N.W., Washington 16, D.C., U.S.A. (1927.)

Stewart, Miss D. D., 21 Keats Grove, Hampstead, London, N.W. 3. (1946.)

Steyaert, R. L., Ing.A.I.G., 159 Rue des Atrébates, Brussels IV, Belgium. (1931.) Phytopathology; *Pestalotia*; *Pestalotiopsis; Truncatella; Ganoderma.*

Stirrup, H. H., M.Sc., N.A.A.S., Shardlow Hall, Shardlow, nr Derby. (1922.) Plant pathology.

Stockdale, Miss P. M., B.Sc., Mycological Reference Laboratory, London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C. 1. (1950.) Medical mycology.

Stone, B. A., B.Sc., Division of Applied Biology, National Research Council, Ottawa, Canada. (1952.) Taxonomy of micro-fungi; biochemistry of fungi, esp. enzymatic aspects.

Storey, H. H., C.M.G., M.A., Ph.D., F.R.S., East Africa Agriculture and Forestry Research Organisation, P.O. Box 21, Kikuyu, Kenya. (1922.) Virus diseases; cereal rusts.

Storey, I. F., B.Sc., Ph.D., D.I.C., N.A.A.S., Anstey Hall, Trumpington, Cambridge. (1941.) Plant pathology; disease measurement; plant disease surveys.

Sullivan, J. B., 5 Dudley Road, Hastings, Sussex. (1951.)

Sutton, W. D., B.A., B.Paed., R.R.4, London, Ontario, Canada. (1953.) Mycetozoa.

Talboys, P. W., Ph.D., D.I.C., M.I.Biol., Plant Pathology Department, Research Station, East Malling, Kent. (1948.) Physiology of parasitism, esp. of vascular mycoses and 'soft rots'; general physiology and biochemistry, including cyto-genetic aspects.

Taylor, J. C., B.Sc., B.Agr., Department of Mycology and Plant Pathology, Queen's University, Belfast, N. Ireland. (1948.)

Taylor, J. W. H., B.Sc., 177 Hinton Way, Great Shelford, nr Cambridge. (1951.) Larger fungi, esp. Agaricales; plant pathology.

Terry, H. J., B.Sc., c/o May & Baker, Ltd., Horticultural Research Station, Boarded Barns Farm, Ongar, Essex. (1953.)

Thomas, D. G., Park Lodge, Binfield, Bracknell, Berks. (1946.)

Thomas, Miss E. M., Garthowen, Neath Road, Maesteg, Glam. (1950.)

Thompson, Miss J., B.Sc., Ph.D., Department of Biology, College of Technology and Commerce, Leicester. (1947.)

Thornton, R. H., M.Agr.Sci., Ph.D., Soil Bureau, Department of Scientific and Industrial Research, Wellington, New Zealand. (1952.)

Thorold, C. A., M.A., A.I.C.T.A., M.I.Biol., Strathculm, Hele, Exeter, Devon. (1952.)

Thorpe, Dr I. G., 11 Butt's Hill Road, Woodley, Berkshire. (1951.)

Threlfall, R. J., B.Sc., A.R.C.S., Kalimna, 58 Green Lane, Worcester Park, Surrey. (1954.) Physiology and biochemistry of fungi; plant pathology; taxonomy.

Thurston, Miss J. M., B.Sc., Rothamsted Experimental Station, Harpenden, Herts. (1942.)

Till, Barry Brayford, B.Sc., 21 Springfield Avenue, Mangotsfield, nr Bristol. (1955.)

Tipler, R. V., B.Sc., A.R.C.S., Imperial Chemical Industries Ltd., Hawthorndale Laboratories, Jealott's Hill Research Station, Bracknell, Berks. (1945.)

Tomkins, R. G., M.A., Ph.D., Director, Ditton Laboratory, East Malling, nr Maidstone, Kent. (1925.)

Tomlinson, J. A., B.Sc., Ph.D., National Vegetable Research Station, Wellesbourne, Warwick. (1948.)

Topping, Mrs M. D., B.Sc., 40 Walpole Street, Derby. (1933.)

Topping, Mrs M. P., B.Sc., Ph.D., Angroban, Fir Tree Road, Leatherhead. (1947.) Discomycetes, esp. inoperculate groups.

Tribe, H. T., School of Agriculture, Cambridge. (1949.)

Trouern-Trend, K., M.Sc., A.R.C.Sc., D.I.C., 11 Hilltop Way, Paul's Dene, Salisbury, Wilts. (1946.)

Tuley, P., B.Sc., Dip.Agr.Sci., D.T.A., c/o Department of Agriculture, Eastern Province, Nigeria. (1951.) Diseases of tropical crops, esp. resistance and breeding aspects.

Tunstall, A. C., 34 Frederick Road, Edgbaston, Birmingham 15. (1933.)

Turner, Miss D. M., M.Sc., Department of Agriculture, The University, Leeds. (1950.)

Turner, Miss E. M., B.A., Ph.D., Old School House, Great Haseley, Oxon. (1940.)

Turner, Mrs F. M., Rosecot, 3 Clevedon Road, Lower Tilehurst, Reading, Berks. (1943.)

Turner, Mrs M., M.Sc., Department of Botany, The University, Nottingham. (1945.)

Twomey, D. G., B.Sc., The Rise, Kittle, Bishopston, Gower, Glamorgan. (1954.) Predacious fungi and their use to control eelworms.

Twyman, Professor E. S., M.Sc., Ph.D., Botany Department, Rhodes University, Grahamstown 1, South Africa. (1942.) General mycology; physiology.

Usher, G., B.Sc., Dip.Ag.Sci., D.T.A., F.R.H.S., 27 Park View Road, Sketty, Swansea, Glamorgan. (1951.) Tree viruses; fungi of tropical trees.

Van Beverwijk, Miss A. L., Eemnesserweg 42, Baarn, Holland. (1947.)

Vanbreuseghem, Professor Dr R., Institut de Medécine Tropicale Prince Leopold, 155 Rue Nationale, Antwerp, Belgium. (1953.) Medical mycology.

Vanterpool, T. C., M.Sc., Department of Botany, University of Saskatchewan, Saskatoon, Canada. (1929.)

Venkatarayan, S. V., 496, IX Cross Road, Malleswaram, Bangalore 3, S. India. (1935.)

Verma, Dr G. S., Botany Department, The University, Lucknow, India. (1951.)

Viennot-Bourgin, Professor G., Institut National Agronomique, 16 rue Claude Bernard, Paris 5^e, France (1936.) Uredinales; Ustilaginales.

Vincent, Miss M., Paddington Baths, London, W. 10. (1949.)

Wadham, Professor S. M., Department of Agriculture, The University, Melbourne, Victoria, Australia. (1922.)

Waldie, J. S. L., B.Sc., C.D.A., Department of Agricultural Botany, The University, Reading. (1925.)

Walker, Mrs J., B.Sc., Ph.D., London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C. 1. (1947.) Medical mycology.

Wallace, E. R., M.A., N.A.A.S., Shardlow Hall, Shardlow, nr Derby. (1934.) Plant pathological terminology; plant disease assessment in the field.

Wallace, G. B., B.Sc.(Agr.), Ph.D., Esk Park, Breckin, Angus, Scotland. (1928.) Plant pathology.

Wallace, T. J., Goodmans, Membury, nr Axminster, Devon. (1951.) Ecology, esp. the fungi of sand dunes; soil fungi; mycorrhiza.

Walne, Mrs P. R., Bryn Siriol, St Agnes Road, Conway, Caern., N. Wales. (1949.)

Walters, N. E. M., B.Sc., Plant Industry Division, C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T., Australia. (1952.)

Wanstall, Mrs R. K. G., Dytchleys, Coxtie Green, Brentwood, Essex. (1952.)

Warcup, J. H., M.Sc., Ph.D., Waite Agricultural Research Institute, Private Mail Bag, Adelaide, S. Australia. (1947.) Soil microbiology; Eurotiaceae.

Ward, Miss G. M., M.Sc., Ph.D., Official Seed Testing Station, Huntingdon Road, Cambridge. (1950.) Plant pathology; seed pathology; soil fungi.

Wardlaw, Professor C. W., Department of Cryptogamic Botany, The University, Manchester 13. (1943.)

Warne, Mrs M. M., 25 Amherst Road, Fallowfield, Manchester 14. (1937.) Pathology of horticultural plants.

Warren, Clara M., M.R.C.S., L.R.C.P., J.P., Fiveways, Leyborne Park, Kew, Richmond, Surrey. (1946.) Medical mycology.

Waterhouse, Miss G. M., M.Sc., Commonwealth Mycological Institute, 18 Cumberland Road, Kew, Surrey. (1927.) Pythiales; Peronosporales; aquatic Phycomycetes; records of Lincolnshire fungi.

Waterston, J. M., B.Sc., Ph.D., A.I.C.T.A., Department of Agriculture, Moor Plantation, Ibadan, Nigeria. (1934.) General mycology and plant pathology.

Watling, R., 20 St Anne's Road, Skircoat Green, Halifax, Yorks. (1954.) Boletales and related genera.

Watson, Miss P., B.Sc., Botany Department, The University, Leeds 2. (1954.) Pigments of agarics, esp. *Russula*; parasites of agarics, esp. *Calcarisporium*.

Watson-Walker, J., B.Sc., M.I.Biol., 17 The Green, Diseworth, Derby. (1949.) Microbiology in relation to chemical technology and engineering; soil microbiology.

Webb, P., Ph.D., Clare Cottage, East Malling, nr Maidstone, Kent. (1938.)

Webb, R. A., B.A., D.Phil., National Hospital, Queen's Square, London, W.C. 1. (1936.)

Webster, B. N., M.A., M.Sc., Tea Research Institute of Ceylon, St Coombs, Talawakelle, Ceylon. (1948.) Plant pathology; mycorrhiza; Hypocreales.

Webster, J., B.Sc., Ph.D., Department of Botany, The University, Sheffield 10. (1945.) Ecology of microfungi; Pyrenomycetes, esp. of grasses; soil fungi; teaching.

Wenham, Mrs S., B.Sc., 10 Archibald Road, Exeter, Devon. (1954.) Medical and veterinary mycology; Eccrinales; yeasts.

Westerdijk, Professor Johanna, 20 Javalaan, Baarn, Holland. (1923.) Cultures of fungi; *Streptomyces*; *Actinomyces*.

Western, J. H., B.Sc., Ph.D., Department of Agriculture, The University, Leeds 2. (1934.) Plant pathology, esp. rusts and smuts; herbage disease fungi; testing for disease resistance.

White, N. H., D.Sc., Faculty of Agriculture, The University, Sydney, New South Wales, Australia. (1944.)

Whitehead, T., D.Sc., A.R.C.S., N.A.A.S., Bryn Adda, Bangor, Caern. (1920.)

Whitehouse, H. L. K., M.A., Ph.D., Botany School, Downing Street, Cambridge. (1948.) Genetics; heterothallism.

Wilkins, W. C., (1947.)

Wilkins, W. H., M.A., D.Phil., St Peter's Hall, Oxford. (1928.)

Wilkinson, E. H., B.Sc., Ph.D., Wye College, Wye, Ashford, Kent. (1938.)

Willetts, H. J., 38 Hillside Terrace, Bedwas, Mon. (1950.)

Williams, P. H., B.Sc., Glasshouse Crops Research Institute, Worthing Road, Rustington, Littlehampton, Sussex. (1930.) Disease of glasshouse crops; soil microbiology in relation to plant diseases.

Wilson, Miss A. P., M.B.E., A.R.C.S., 7A Arlington Drive, Nottingham. (1929.)

Wilson, A. R., Ph.D., B.Sc., M.S., Nottingham University School of Agriculture, Sutton Bonnington, Loughborough. (1933.) Pathology of the potato; harvesting, storage, grading, transport and market presentation of the potato crop.

Wilson, Miss I. M., B.Sc., M.Sc., Ph.D., Department of Botany, University College of Wales, Aberystwyth. (1938.) Cytology and life-history of Ascomycetes; marine fungi; British species of the genus *Halophiobolus* and fungi on wood submerged in the sea.

Wilson, J. F., B.Sc., Juniper Cottage, Nettlestead, nr Maidstone, Kent. (1950.)

Wilson, M., D.Sc., A.R.C.S., F.L.S., Royal Botanic Garden, Edinburgh. (1912.)

Wiltshire, S. P., M.A., D.Sc., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1920.) Plant pathology, esp. fruit diseases; *Alternaria* and *Stemphylium*.

Winkel, Miss Helena Te, B.Sc., 28 Park Way, Golders Green, London, N.W. 11. (1935.) Predacious fungi.

Wolf, Dr F. T., A.B., M.A., Ph.D., Vanderbilt University, Nashville, Tennessee, U.S.A. (1940.) Physiology, esp. nutrition and metabolism.

Wood, J. S. D., B.Sc., Botany Department, Hatherly Laboratories, University College, Prince of Wales Road, Exeter, Devon. (1954.)

Wood, R. K. S., A.R.C.S., Ph.D., Department of Botany, Imperial College of Science and Technology, South Kensington, London, S.W. 7. (1946.) General plant pathology, esp. physiological aspects; physiology of nutrition.

Wood-Baker, Mrs Audrey, B.Sc., Birkbeck College, Malet Street, London, W.C. 1. (1948.) Physiology, esp. gaseous requirements of moulds.

Woodward, R. C., B.Sc., M.A., Ph.D., Overseas Development Department, Plant Protection, Ltd., Bolton House, 61 Curzon Street, Piccadilly, London, W. 1. (1924.) Chemical methods of controlling fungous diseases.

Wormald, H., D.Sc., A.R.C.S., 66 Bower Mount Road, Maidstone, Kent. (1921.)

Wright, D. G., B.Sc., Imperial Chemical Industries, Ltd., Dyestuffs Division, Trafford Park, Manchester 17. (1950.) Industrial mycology; antibiotics; Pyrenomycetes; Hyphomycetes.

Wright, F. R. E., Braunton, N. Devon. (1946.)

Wright, Miss J. M., Imperial Chemical Industries, Ltd., Akers Research Laboratories, The Frythe, Welwyn, Herts. (1949.)

Yuill, E., 35 Askham Lane, Acomb, York. (1931.)

Associate Members

Bailey, A. G., 177 Langley Way, West Wickham, Kent. (1954.) General mycology; Mycetozoa.

Bennett, Mrs H. Sterndale, Oaken Wood, Wateringbury, Kent. (1950.)

Bray, Miss M. F., Imperial Chemical Industries, Ltd., Hawthorndale Laboratories, Jealott's Hill Research Station, Bracknell, Berks. (1949.)

Briggs, Mrs Elsie A., 5 Redway Drive, Twickenham, Middx. (1953.)

Brokenshire, F. A., 2 Rock Avenue, Barnstaple, N. Devon. (1946.)

Brown, Miss J. E., 4 Fairfield Road, Woodford Green, Essex. (1948.)

Brown, Miss Margaret E., B.Sc., 11 Royal Gardens, Boston Road, Hanwell, London, W.7. (1953.)

Brunner, Miss N., 9 Upper Clanbrasil Street, Dublin, Eire. (1949.)

Callan, I. W. McC., B.Sc., Dip.Agr.Sc., 19 Alexandra Road, Reading, Berks. (1950.)

Charlton, J. L., B.Sc., Dip.Bact., Imperial Chemical Industries, Ltd., Hawthorndale Laboratories, Jealott's Hill Research Station, Bracknell, Berks. (1947.)

Clements, Miss C. A., B.Sc., Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks. (1952.)

Dick, M. W., 5 Fairway, East Wimbledon, London, S.W. 20. (1954.)

Dobbs, Mrs C. G., Bodifyr, Bangor, Caern. (1947.)

Elias, R. S., B.Sc., A.R.C.S., 22 Rythe Road, Claygate, Surrey. (1952.)

Ellis, Mrs M. B., 20 Palewell Park, East Sheen, London, S.W. 14. (1947.)

Geoghegan, Miss M. E., Ottershaw School, nr Chertsey, Surrey. (1950.)

Gobbett, R. H., 11 Rostrevor Road, Fulham, London, S.W. 6. (1948.)

Godfrey, Miss R. M., B.Sc., 32 Richmond Park Road, Bristol 8. (1954.) Hypogeous fungi; ecology.

Goodhue, R. D., M.S.R., 34 Marshall Road, Rainham Mark, Gillingham, Kent. (1953.)

Grasemann, Miss Aline, 12 Dry Hill Road, Tonbridge, Kent. (1955.) Larger fungi.

Gray, Miss M. R., 43 Woodcroft Avenue, Mill Hill, London, N.W. 7. (1947.)

Gregory, Mrs M. F., 47 Milton Road, Harpenden, Herts. (1945.)

Hilhouse, Miss A. M., 6 Cornwall Road, Uxbridge, Middx. (1953.)

Howarth, Miss S., 201 King's Road, Chelsea, London, S.W. 3. (1951.)

James, L., 19 Bushey Road, Ickenham, Uxbridge, Middx. (1947.)

Jones, Miss P. R., 2 Birchwood Mansions, Muswell Hill, London, N. 10. (1950.)

Jupp, Rev. T. H., St Peter's Parsonage, Belsize Square, London, N.W. 3. (1952.)

Kelsall, Mrs H. M., 21c Stanhope Road, Highgate, London, N. 6. (1947.)

King, J. M. B., Ph.C., 23 Lyncroft Gardens, Ealing, London, W. 13. (1945.) Larger fungi, esp. Boleti.

Lock, Miss H. M., 99 Thames Drive, Leigh-on-Sea, Essex. (1947.)

Martin, Miss J., B.Sc., 9 Enmore Gardens, East Sheen, London, S.W. 14. (1947.)

Metcalfe, C. R., B.A., Ph.D., Jodrell Laboratory, Royal Botanic Gardens, Kew, Surrey. (1947.)

Molesworth, Miss B., Area Education Offices, Harrington Road, Workington, Cumberland. (1945.)

Montgomery, W. E., Forensic Science Laboratory, Shakespeare Street, Nottingham. (1950.)

Moore, Mrs W. C., Vallis, Amenbury Lane, Harpenden, Herts. (1945.)

Neville, W. J. J., 10 Penmaen Road, Conway, N. Wales. (1949.) Photography, esp. of Basidiomycetes.

Nye, A. L., M.A., Barrister-at-Law, Annat Lodge, Perth, Scotland. (1949.) Edible fungi.

Pollard, Mrs R. M., Whitelands, Hollist Lane, Midhurst, Sussex. (1949.)
Prentice, Mrs M. M., 84 Station Road, Harpenden, Herts. (1945.)
Ralph, P. H. A., 6A Ellenslea Road, St Leonards-on-Sea. (1950.)
Rapson, H. D., Flat 3, Brockham Park, Betchworth, Surrey. (1950.)
Reid, Mrs P. M., B.Sc., Commonwealth Mycological Institute, Ferry Lane, Kew, Surrey. (1951.)
Smieton, Margaret Judith, B.Sc., 14 St George's Road, St Margaret's, East Twickenham, Middx. (1954.) Plant pathology; horticulture.
Smith, R. S., B.Sc., 58 Woodland Gardens, Isleworth, Middx. (1954.)
Tipler, Mrs M. K., B.Sc., 2 Waterside Lodge, Raymead Road, Maidenhead, Berks. (1945.)
Webb, Miss M. B., 67 Greenwood Road, Mitcham, Surrey. (1948.)
Weston, Mrs S. D., Howe Farm House, Huntingdon Road, Cambridge. (1948.)
Wheeler, B. E. J., No. 2 Officers' Mess, Royal Air Force, St Athan, Glam. (1949.)
Whitton, B. A., 91 The Quadrant, Wimbledon, London, S.W. 20. (1952.)
Yalden, Miss M. E., 4 Somerfield Terrace, London Road, Maidstone, Kent. (1948.)

Members are requested to notify the Secretary (J. Webster) *and Treasurer* (W. Buddin) *of any change of address*

RULES

Society's Name and Object

1. The Society shall be called 'The British Mycological Society', and its object shall be the study of Mycology in all its branches.

Members of Society

2. The Society shall consist of Honorary Members, Members (including Foundation Members*), and Associates; the number of Honorary Members shall be limited to 12 at any one time, but the numbers of Members and Associates shall be unlimited.

Honorary Members

3. Honorary Members shall be persons of pre-eminence in Mycology, or who have rendered special service to the Society.

Officers

4. The Officers of the Society shall consist of a President, two or more Vice-Presidents, Treasurer, Secretary, Foray Secretary, Secretary of the Plant Pathology Committee and Editor or Editors. They shall be elected annually, at the Annual General Meeting of the Society.

Government of Society

5. The government of the Society shall be vested in a Council, which shall consist of the President and other Officers, together with nine other Members who shall be elected annually at the Annual General Meeting, three of whom shall be elected to replace three retiring members, who shall not be eligible for immediate re-election. The Members to retire shall be those who have been longest in office, or, where there is equality, those determined by ballot. The retiring President shall become a Vice-President for a period of two years. Ex-Presidents who served their year of office prior to 31 December 1936 are *ex-officio* members of the Council.

Period of Office

6. The Officers and Council shall hold office from 1 January following their election.

Plant Pathology Committee

7. The special interests of Plant Pathology shall be delegated to an executive committee, to be called the Plant Pathology Committee of the British Mycological Society. The Committee shall consist of the President and Secretary, *ex-officio*, and twelve other Members of the

---

* Foundation Members are those Members who joined the Society previous to the limit of 100 Members having been attained. This was reached 22 October 1903.

Society. The latter shall be elected annually at the Annual General Meeting, and three shall retire each year and shall not be eligible for immediate re-election. The Members to retire shall be those who have been longest in office, or, where there is equality, those determined by ballot.

The Officers shall consist of a Chairman and a Secretary, to be elected by the Committee each year.

At least two meetings shall be held every year, six Members to form a quorum.

The Committee shall have power to appoint for any special purpose a sub-committee consisting either wholly or partly of members of the Committee.

Election of Members

8. Honorary Members shall be elected only at a meeting of the Society by a majority of the Members then present.

Every candidate for election as a Member shall be proposed by two Members who shall sign a certificate (see Appendix) of recommendation, one at least of the proposers so certifying from personal knowledge. Each candidate shall sign an undertaking to abide by the Rules if elected (see Appendix). They shall be elected by a majority of the Members present at any meeting of the Society or by the President and Officers of the Society.

Subscription

9. All Members shall pay a minimum annual subscription of thirty shillings, Foundation Members paying five shillings, due on 1 January in each year. Honorary Members shall be exempt from any such payment.

Members of at least 25 years' standing who are 65 years old (or over 60 if already in retirement) may pay a subscription at half the normal rate, if they have not signed a Covenant, or when their Covenant expires.

A Member wishing to retire from the Society shall give notice to the Secretary or Treasurer in writing before 1 December of the previous year.

Associates

10. All Associates shall be proposed by two Members. They shall be elected by a majority of the Members present at a meeting of the Society and shall pay an annual subscription of ten shillings. They shall be eligible to attend the Society's meetings and forays but not to vote at any meeting or to receive the Transactions.

Meetings

11. The Society shall hold one or more meetings annually, at a place and time determined by the Members at the preceding Annual General Meeting or by the Council.

Accounts

12. At the Annual General Meeting in each year the Treasurer shall present duly audited accounts.

Alteration of Rules

13. The Rules shall not be altered except by a two-thirds majority of the Members present at an Annual General Meeting. A printed copy shall be sent to every Member on election, and in the event of alterations, to all Members.

APPENDIX

Form of proposal for Membership or Associateship of the British Mycological Society

NAME ....
(Block capitals)

DEGREES, ETC. ....

ADDRESS ....
(Block capitals)

....

being desirous of becoming * a Member an Associate of the British Mycological Society, we, the undersigned Members of the Society, certify that we consider h to be a desirable * Member Associate of the Society, and beg to recommend h for election.

Dated this day of 19

PROPOSED BY

.... (From personal knowledge)

....

Certificate to be signed by the Candidate

I hereby certify that I desire to become * a Member an Associate of the British Mycological Society and that I will abide by the Rules if elected.

....

* Delete where not applicable.

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